ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

PhD THESIS

Oğuzhan TİMUR

DESIGN AND IMPLEMENTATION OF A WIRELESS SENSOR NETWORK FOR ENERGY MONITORING, ANALYSIS AND MANAGEMENT IN SMART BUILDINGS

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Doctor of Philosophy by the board of jury on 24/01/2018.

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ABSTRACT

PhD THESIS

DESIGN AND IMPLEMENTATION OF A WIRELESS SENSOR NETWORK FOR ENERGY MONITORING, ANALYSIS AND MANAGEMENT IN SMART BUILDINGS

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In this thesis, a smart building management system (SBMS) is developed to be used in households and buildings by employing ZigBee wireless communication protocol. In order to program microcontroller cards utilized in SBMS, a special algorithm is enhanced for code standardization. The system consisting of energy management section (EMS), security check section (SCS), and fire detection control section (FDCS) is executed in the main system room of hospital information management system in Çukurova University Balcalı Hospital. In EMS, the smart plug is firstly designed to measure electrical quantities. Data obtained from measurements in the server and air conditioners are evaluated to predict future consumption by artificial intelligence methods. Furthermore, three split-type air conditioners are sequentially operated with respect to measured temperature and humidity values. Additionally, LED dimming study is realized instead of traditional lighting techniques. According to analyzes and studies in the scope of this thesis, energy savings of about 22% can be achieved. Standardized codes in EMS can be used in SCS and FDCS, and it is proved that developed codes can be employed for all Arduino cards. It is considered that the developed SBMS with additional future works will significantly contribute to demand side management for further studies.

Keywords: Energy Efficiency, Energy Saving, Energy Management, Wireless Communication, ZigBee

ÖZ

DOKTORA TEZİ

AKILLI BİNALARDA ENERJİ İZLEME, ANALİZ VE YÖNETİMİ İÇİN KABLOSUZ ALGILAYICILI AĞ UYGULAMASI TASARIMI VE GERÇEKLEŞTİRİLMESİ

Oğuzhan TİMUR

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Bu tezde, konut ve binalarda kullanılmak amacıyla ZigBee kablosuz haberleşme protokolü kullanılarak bir akıllı yönetim sistemi (AYS) geliştirilmiştir. AYS'de kullanılan mikro denetleyici kartları programlamak için, özel bir algoritma geliştirilerek kodlarda standartlaşmaya gidilmiştir. Enerji yönetim bölümü (EYB), güvenlik kontrol bölümü (GKB) ve yangın algılama kontrol bölümlerinden (YAKB) oluşan sistem Çukurova Üniversitesi Balcalı Hastanesi, hastane bilgi yönetim sistemi ana sistem odasında çalıştırılmaktadır. EYB'de öncelikle akıllı priz tasarımı yapılarak elektriksel niceliklerin ölçülmesi sağlanmıştır. Sunucu ve klimalarda yapılan ölçümlerden elde edilen veriler yapay zeka metodları ile değerlendirilerek gelecekteki tüketim için tahminlerde bulunulmuştur. Ayrıca, sistem odası içindeki üç adet split klimanın, ölçülen sıcaklık ve nem değerlerine göre sıralı olarak çalıştırılması sağlanmıştır. Ek olarak, aydınlatma sisteminde klasik aydınlatma yöntemleri yerine LED loşlama çalışması gerçekleştirilmiştir. Tez kapsamındaki analiz ve çalışmalara dayanarak, %22 civarında enerji tasarrufu yapılabileceği tespit edilmiştir. EYB'de standartlaştırılan kodlar GKB ve YAKB bölümlerinde de kullanılarak geliştirilen kodların tüm Arduino kartlar için kullanılabileceği kanıtlanmıştır. Geliştirilen AYB'nin gelecek de yapılacak olan ek çalışmalarla, talep tarafı yönetimine büyük katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Enerji Verimliliği, Enerji Tasarrufu, Enerji Yönetimi, Kablosuz Haberleşme, ZigBee

EXTENDED SUMMARY

Energy is an indispensable necessity for human life. Technological developments, which push imagination limits of mankind, have caused an increase in energy demand. The rapid depletion of fossil fuels has enhanced the value of energy by making energy efficiency and energy saving compulsory. Dependency on fossil fuels has not died out completely because of the fact that the amount of energy production from renewable energy sources does not cover the whole demand. Utilization of advanced technology with an ascending trend indicates that increase in energy consumption will proceed in terms of future expectations.

Expanding awareness related to conscious consumption becomes more of an issue in order to avoid a future energy crisis. It is meaningless to estimate how much energy is saved without measuring how much energy is consumed. In such a case, it is impossible to mention about energy saving or energy efficiency. It is probable to determine the energy consumption amount of a device by carrying out measurement of the used device. Evaluating the measured values and creating scenarios with respect to the results of these evaluations are essential steps in energy management. By energy management, while energy saving is realized by preventing from unnecessary use of existing energy, energy efficiency is also provided by consuming less energy simultaneously.

Auto-measurement of energy consumption amount via a computer is important from the point of view of data integrity. As a result of the measurements, saving scenarios should be identified by creating energy consumption profile of each device. Energy savings should be accomplished without lowering current living standards. Control and management by developing smart systems rather than direct human controlled inspections will increase the efficiency.

When energy consumption is investigated on a sectoral basis, it is seen that buildings have a significant place, because commonly use of electrical energy in buildings is unavoidable in today’s circumstances. According to the construction of

smart buildings and production of smart devices, more efficient utilization of energy sources has been provided. Owing to embedded software programs, self-operating systems have been devised without the need of expensive computers. New smart systems have been developed by adding data storage units and the Internet, and this new system is named as the Internet of things in the literature. Non-smart devices are turned into smart devices by creating smart networks which have provided communication particularly by preferring wireless connections among each device and between larger systems.

In this study, articles and conference papers of major publishers such as IEEE, IEE, and Elsevier related to the thesis have been firstly surveyed and comprehensively summarized in order to follow the recent advances in the literature.

Afterwards, a smart building management system (SBMS) which communicates wirelessly has been developed to utilize in households and buildings. After detailed investigations, it has been decided to use Arduino cards for physical installation of smart systems. The ATMEL microcontrollers on the Arduino have been programmed by using the C++ programming language, which has established the coordination between sensors and actuators. Arduino cards used as end and routing devices have been communicated bi-directionally with the Arduino card used as coordinator node point by using ZigBee wireless communication protocol. End devices have been connected to routing devices by using star topology and routing devices have been connected to the coordinator node point by the same topology as well.

When the previous studies are investigated, it is seen that separate software programs have been developed for each embedded card. In this thesis, all of the embedded cards are classified into two groups with respect to the purpose of use. As a consequence of the classification, a single software program code for each class has refined for standardization. If there is a need for additional new cards to the system later, one of the standardized code lines will be loaded and executed according to the intended use of the card. Standardized codes and load over an embedded card with a limited resource has been lightened by transferring to the server. The limited resources that embedded cards have are too small in comparison with the resources that advanced computers have. This study is the first of its kind in the literature when similar studies in the past are investigated.

After physical installation and coding of embedding cards are done, a Windows based desktop application operating on the server computer has been developed for reading data on these cards, storing the read data, analyzing the stored data, reporting, and management. Created software by using Delphi programming language is the main software program of SBMS. All cards and all parameters belong to these cards are identified by using this software program. Furthermore, all of the obtained data are stored via this software program in a database file on the same server. FireBird database has been chosen as being open source, free, and compatible with Delphi. Software of the server is not only used for all identifications and parameter settings by people who have a high level of administrative authorization but also holds all data and reports that users can access at the same time. Users can remotely access and control devices by connecting to server software. Users can either connect to SBMS via a desktop application or different applications developed for web-based or mobile devices. Instead of using separate languages for user platforms, the Delphi compiler, which can be converted to an Android-based application by making minor changes in the desktop application, has been chosen as the programming language. Additionally, the application has been turned into web-based by Thinfinity VirtualUI software of Cybele Software after some small revisions. Hence, users can govern devices at the remotest point according to their pre-defined authorizations in the system via three different graphical interfaces in order to access SBMS and database. Obtained data from measurement and monitoring in the SBMS have been analyzed by using artificial neural networks (ANN), the most efficient utilization of energy has been provided at the most appropriate time by load forecasting.

When the implemented SBMS is investigated, it is seen that it consists of three sections which are energy management section (EMS), security check section (SCS), and a fire detection control section (FDCS).

EMS constitutes the backbone of the developed system. In EMS, a smart plug (SP) has been aimed to design in order to measure the electrical energy consumption of the devices real-timely. Energy saving has been provided by using embedded systems and wireless network protocol for measuring, monitoring, and controlling of electrical energy. Then, by comparing the current consumption with past consumptions, a consumption pattern has been determined for each measured device.

By the SP design, electrical energy consumption of the devices has been measured by the electric plug and delivered to the server software program. In order to determine how much electrical energy is consumed by which device, it is adequate to connect power supply of the device to the designed SP. Values such as current, voltage, temperature, humidity, cos φ, and frequency have been measured and saved by sensors on SP with respect to the specified sampling period. The amount of consumed power and energy of the device has been calculated with respect to the values. A software program operating on the server and all data received from the SP have been stored in database files. Peak times and maximum energy consumption values in a day can be determined by analysis of the data in the database. Measurement results of the developed SP have been tested by a calibrated device which measures more precisely. After test results, the error of the developed SP has been confirmed as at most 2%. In SBMS, maximum and minimum levels of measured values have been identified parametrically and in case of a violation of these threshold values, an interruption in energy has been provided. Owing to this feature, the risk of electric shock has been kept at a minimum.

Secondly, LED lamp dimming study has been realized in EMS. Unnecessary consumption has been prevented from using dimmable LED lamps instead of existing fluorescent lamps with magnetic ballast. If there is no movement in the corridor, LED lamps are maximally dimmed for illumination at the minimum level. A movement sensitive system has been developed by using presence sensors. An approximate saving of 14% is seen in the system when it is compared to fluorescent lamp with magnetic ballast that continuously operates at maximum power.

Lastly in EMS, a study related to split type air conditioners in system room has been conducted. Temperature and humidity values of the system room have been controlled and stored via temperature and humidity sensors in the ambient. In the conducted study, button configurations of the air-conditioner have been recorded in SBMS by utilizing infrared (IR) receiver circuit. Then, air conditioner controls have been carried out with identified buttons by using IR transmitter circuit. By controlling air conditioners according to read temperature and humidity values, their activation and deactivation have been provided sequentially. A rough saving of 30% has been provided by developing such a system instead of operating all air conditioners simultaneously.

In addition to studies that increase energy efficiency, it is proved by other applications that realized applications can also be used in the fields of fire detection and security control. Some applications can be employed jointly in more than one area.

In the applications, it is seen that movements and presence sensors are used in order to detect living beings in the room. However, movement and presence sensors cannot detect interior entity during a study that will be motionless for a long time because of their motion-sensitive nature. In the study that is conducted in FDCS, when a high value is read on one of gas, flame, smoke, and temperature sensors, activation of alert and picture message system has been provided. Authorized personnel can monitor the circumstance of the system room by checking incoming picture message. Additionally, the personnel can activate fire extinguishing system remotely thanks to Android or web based application. When thermal presence sensor supplied from abroad has been activated, it is seen that the sensor can be operated in maximum 1 m^2 area effectively. Due to expensiveness and tightness of the thermal presence sensor, an extra IP camera has been added to the system. Therefore, manual control has been provided.

SCS constitutes the third section of SBMS. If it is desired to enter the system room after the hour 17:00, entrance with a keypad or fingerprint control has been ensured. A login with three false keypad combination or three unidentified fingerprint in SBMS database causes a termination of entry, an alarm activation, and sending short message to authorized personnel. The personnel, who receives the short message, can monitor by using IP camera which is identified in FDCS and in this section as well.

All embedded cards employed in SBMS is fed externally by battery or adapter. Use of photovoltaic panel in the department of Electrical and Electronics Engineering is foreseen to feed in these devices. A solar tracking system (STS) has been designed by utilizing embedded card is developed to use this panel more efficiently. Owing to STS, it is ensured that the photovoltaic panel tracks sun position in the horizontal axis. Due to unsuitable physical location of the system room, developed STS is operated on the department building.

Realized SBMS is parametric and has flexible structure. The conducted study is expendable without depending on a specific brand. This project can be utilized in different buildings for diversified purposes. All of the design and experimental works done in the scope of this thesis are presented in the following pages in details.

GENİŞLETİLMİŞ ÖZET

Enerji insan yaşamı için vazgeçilmez bir gereksinimdir. İnsanoğlunun hayal gücünün sınırlarını zorlayan teknolojik gelişmeler, enerjiye olan talebin artmasına neden olmuştur. Mevcut fosil yakıtların hızla tükenmesi, enerjinin değerini arttırarak, enerjiyi daha verimli kullanmayı ve enerji tasarrufu yapmayı zorunlu hale getirmiştir. Yenilenebilir enerji kaynaklarından elde edilen enerji üretim miktarının tüm talepleri karşılayamaması yüzünden fosil yakıtlara olan bağımlılık tamamen ortadan kalkmamıştır. Gelişmiş teknolojilerin artan bir trendle kullanılması, gelecek beklentileri açısından enerji tüketimindeki artışın devam edeceğini göstermektedir.

Bilinçli tüketim ile ilgili farkındalığı artırmak, gelecekteki enerji krizlerinden kaçınmak için önem arz etmektedir. Ne kadar enerji tüketildiğini bilmeden ne kadar enerji tasarrufu yapılacağını kestirmek anlamsız olacaktır. Böyle bir durumda, enerji tasarrufu yapılmasından veya enerjiyi verimli kullanmaktan bahsetmek imkansızdır. Kullanılan cihazlar üzerinde ölçümler yapılarak, cihazın enerji tüketim miktarını tespit etmek mümkündür. Ölçülen değerlerin kıymetlendirilmesi ve bu değerlendirmeler sonucu ortaya çıkacak olan durumlara göre senaryolar geliştirilmesi, enerji yönetiminin vazgeçilmez adımları arasındadır. Enerji yönetimi ile mevcut enerjinin gereksiz kullanımından kaçınılarak enerji tasarrufu gerçekleştirilirken, eşzamanlı olarak daha az enerji tüketilerek enerji verimliliği de sağlanır.

Tüketilen enerji miktarının bir bilgisayar yardımı ile otomatik olarak ölçülmesi veri bütünlüğü açısından önemlidir. Yapılan ölçümler sonucunda, her cihazın kendi enerji profili oluşturularak tasarruf yapılabilecek durumlar tespit edilmelidir. Enerji tasarrufu mevcut hayat standartları düşürülmeden gerçekleştirilmelidir. Doğrudan insan kontrolü ile gerçekleştirilecek denetimlerden ziyade akıllı sistemler geliştirilerek kontrol ve yönetim yapılması verimliliği arttıracaktır.

Sektörel bazda enerji tüketimi incelendiğinde, binaların önemli bir yere sahip olduğu görülür, çünkü elektrik enerjisinin binalarda yaygın olarak kullanılması günümüz koşullarında kaçınılmazdır. Akıllı binaların inşası ve akıllı cihazların üretilmesiyle, enerji kaynaklarının daha verimli kullanılması sağlanmıştır. Gömülü yazılımlar sayesinde pahalı bilgisayarlara ihtiyaç duyulmadan, kendi kendine çalışan sistemler geliştirilmiştir. Bu sistemlere veri depolama birimleri ve Internet eklenerek yeni akıllı sistemler geliştirilmiş ve bu yeni sistem nesnelerin Interneti kavramı ile literatürdeki yerini almıştır. Cihazların özellikle kablosuz bağlantılar tercih edilerek birbiriyle ve daha büyük sistemlerle haberleşmesini sağlayan akıllı ağların oluşturulmasıyla, akıllı olmayan cihazların akıllı cihazlar haline getirilmesi sağlanmıştır.

Bu çalışmada ilk olarak, literatürlerdeki son gelişmeleri takip etmek amacıyla, IEEE, IEE ve Elsevier gibi önemli yayıncıların tez ile ilgili makale ve konferans bildirileri incelenerek kapsamlı olarak özetlenmiştir.

Daha sonra konut ve binalarda kullanılmak üzere kablosuz olarak haberleşen bir akıllı yönetim sistemi (AYS) geliştirilmiştir. Detaylı yapılan araştırmalar sonrasında akıllı sistemlerin fiziksel olarak kurulumu için Arduino kartların kullanılmasına karar verilmiştir. Arduino üzerinde bulunan ATMEL mikro denetleyicileri, C++ programlama dili kullanılarak programlanmış ve bu sayede sensörler ile aktüatörler arasında koordinasyon kurulmuştur. Uç ve yönlendirici cihaz olarak kullanılan Arduino kartlar, koordinatör düğüm noktası olarak kullanılan Arduino kart ile ZigBee kablosuz haberleşme protokolü kullanılarak iki yönlü olarak haberleştirilmiştir. Uç cihazlar yönlendirici cihazlara ve yönlendirici cihazlarda koordinatör düğüm noktasına yıldız topoloji kullanılarak bağlanmıştır.

Daha önce gerçekleştirilen çalışmalar incelendiğinde, kullanılan gömülü kartların her biri için ayrı bir yazılım geliştirildiği görülmüştür. Bu tezde, tüm gömülü sistem kartları kullanım amacı dikkate alınarak iki grup da sınıflandırılmıştır. Yapılan sınıflandırma sonucu, her bir sınıf için tek bir yazılım kodu geliştirilerek standartlaşmaya gidilmiştir. Sisteme daha sonra yeni kartlar eklenmek istendiğinde, kartın kullanım amacına göre standartlaştırılmış kod satırlarından biri yüklenerek çalıştırılacaktır. Standartlaşan kodlar ile limitli kaynağa sahip olan gömülü kart üzerindeki yük, sunucu üzerine aktarılarak hafifletilmiştir. Gömülü kartların sahip olduğu sınırlı kaynaklar, gelişmiş bilgisayarların sahip olduğu kaynaklar ile kıyaslanamayacak kadar küçüktür. Yapılan bu çalışma, daha önceki yapılan benzer çalışmalar incelendiğinde, literatürde ilk olma özelliğine sahiptir.

Gömülü kartların fiziksel kurulumu ve kodlamaları yapıldıktan sonra bu kartlar üzerindeki verilerin okunması, okunan verilerin depolanması, depolanan verilerin analiz edilmesi, raporlanması ve yönetimi için sunucu bilgisayarı üzerinde çalışan Windows tabanlı bir masaüstü uygulaması geliştirilmiştir. Delphi programlama dili kullanılarak geliştirilen yazılım AYS nin ana yazılımı niteliğindedir. Tüm kartlar ve bu kartlara ait tüm parametreler bu yazılım kullanılarak tanımlanmaktadır. Ayrıca elde edilen tüm veriler bu yazılım aracılığıyla aynı sunucu üzerinde bulunan veri tabanı dosyasına kaydedilmektedir. FireBird veri tabanı, açık kaynak kodlu, ücretsiz ve Delphi ile uyumlu çalıştığı için tercih edilmiştir. Daha çok yönetici yetkisine sahip olan kişilerin tüm tanımlama ve parametre ayarları için kullandıkları bu sunucu yazılımı, aynı zamanda kullanıcıların ulaşabilecekleri tüm veriler ile raporlamaları da üzerinde bulundurmaktadır. Kullanıcılar, cihazları sunucu yazılımına uzaktan bağlanarak erişebilirler ve kontrol edebilirler. Kullanıcılar geliştirilen masaüstü uygulama ile AYS ye bağlanabilecekleri gibi web tabanlı veya mobil cihazlar üzerinden de geliştirilen farklı yazılımlar ile sisteme erişebileceklerdir. Kullanıcı platformları için ayrı ayrı diller kullanılarak yazılım yapılması yerine, masaüstü olarak yazılan uygulamanın küçük değişiklikler yapılarak Android tabanlı uygulamaya dönüştürülebileceği Delphi derleyicisi, programlama dili olarak tercih edilmiştir. Ek olarak, yazılan uygulama küçük değişiklikler yapılarak, Cybele Software firması tarafından geliştirilen Thinfinity VirtualUI software ile Web tabanlı hale getirilmiştir. Böylece kullanıcılar sistemde tanımlanan yetkilerine göre 3 farklı grafik arabirimi üzerinden AYS ve veritabanına erişerek en uç noktadaki cihazları yönetebileceklerdir. AYS de yapılan ölçümler ve izlemeler sonucunda elde edilen veriler, Yapay Sinir Ağları (YSA) kullanılarak analiz edilmiş, yük tahminleri yapılarak, enerjinin en uygun zamanda en verimli kullanılması sağlanmıştır.

Geliştirilen AYS içerik olarak incelendiğinde, ana hatlarıyla enerji yönetimi bölümü (EYB), güvenlik kontrol bölümü (GKB) ve yangın algılama kontrol bölümü (YAKB) olmak üzere üç kısımdan oluştuğu görülmektedir.

EYB oluşturulan sistemin ana omurgasını oluşturmaktadır. EYB de cihazların tükettikleri elektrik enerjisi miktarını gerçek zamanlı olarak ölçmek amacıyla, bir akıllı priz (AP) tasarımı gerçekleştirilmiştir. Elektrik enerjisinin gömülü sistemler ve kablosuz ağ protokolü kullanılarak ölçümü, izlenmesi, analiz edilmesi ve yönetilmesi gerçekleştirilerek enerji tasarrufu yapılması sağlanmıştır. Daha sonra mevcut tüketim durumu ile geçmişteki tüketim durumları karşılaştırılarak, ölçüm yapılan her cihaz için tüketim eğilim modeli belirlenmiştir.

AP tasarımı ile cihazların tükettiği elektrik enerjisi, takılı olduğu elektrik prizi tarafından ölçülerek sunucuda çalışan programa iletilmiştir. Hangi cihazın ne kadar elektrik enerjisi tükettiğini tespit etmek için cihazın elektrik beslemesinin tasarlanan akıllı prize bağlanması yeterlidir. Belirlenen örnek alma süresine göre, AP üzerinde bulunan algılayıcılar sayesinde, akım, gerilim, sıcaklık, nem, cos φ, frekans gibi değerler ölçülerek kayıt altına alınmıştır. Cihazın tükettiği güç ve enerji miktarı okunan değerler sayesinde hesaplanmıştır. Sunucu üzerinde çalışan program ile akıllı prizden gelen tüm veriler, veri tabanı dosyalarına kaydedilmiştir. Veri tabanında tutulan verilerin analiziyle, cihazın gün içinde en yüksek enerji tükettiği saatler, en yüksek enerji tüketim miktarı gibi değerler belirlenebilmiştir. Geliştirilen akıllı prizin ölçüm sonuçları, daha hassas ölçüm yapan kalibrasyonlu bir cihazla test edilmiştir. Test sonucunda, geliştirilen akıllı prizin hata değerinin en fazla 2% olduğu tespit edilmiştir. AYS de, ölçülen değerlerin maksimum ve minimum seviyeleri parametrik olarak tanımlanmış ve bu eşik değerlerinin ihlal edilmesi durumunda enerjinin kesilmesi sağlanmıştır. Bu özellik yardımı ile elektrik çarpma riski en aza indirgenmiştir.

İkinci olarak, EYB'de LED lamba loşlama çalışması gerçekleştirilmiştir. Mevcutta var olan manyetik balastlı flüoresan lamba yerine, dimlenebilen LED lambaların kullanılması ile gereksiz tüketimin önüne geçilmesi sağlanmıştır. Koridor da herhangi bir hareketin mevcut olmadığı durumda LED lambalar maksimum oranda kısılmış olup, minimum derecede aydınlatma yapmaktadır. Varlık sensörleri yardımıyla harekete duyarlı bir sistem geliştirilmiştir. Sürekli maksimum güçte çalışan manyetik balastlı flüoresan lamba ile kıyaslandığında, yaklaşık olarak % 14 oranında tasarruf yapıldığı görülmektedir.

Son olarak EYB bölümünde sistem odasında bulunan split klimalarla ilgili bir çalışma yapılmıştır. Ortamdaki sıcaklık ve nem sensörleri ile sistem odasının sıcaklık ve nem değerleri kontrol edilerek kayıt altına alınmıştır. Yapılan çalışmada, kızılötesi alıcı devresi kullanılarak, klimanın tuş fonksiyonları AYS üzerine kaydedilmiştir. Daha sonra kızılötesi verici devresi kullanılarak tanımlanan tuşlar ile klima kontrolleri gerçekleştirilmiştir. Okunan sıcaklık ve nem değerlerine göre klimalar kontrol edilerek sıralı olarak devreye girip çıkmaları sağlanmıştır. Tüm klimaların aynı anda çalışması yerine böyle bir sistemin geliştirilmesi, yaklaşık olarak %30 oranında tasarruf yapılmasını sağlamıştır.

Enerji verimliliğini arttıracak çalışmalara ek olarak, gerçekleştirilen uygulamaların yangın algılama kontrol ve güvenlik kontrol alanlarında da kullanılabileceği, yapılan diğer uygulamalarla kanıtlanmıştır. Bazı uygulamalar birden fazla alan içinde ortak kullanılabilmektedir.

Yapılan uygulamalarda oda içindeki canlı varlığının tespit edilmesi için hareket ve varlık sensörlerinin kullanıldığı görülmüştür. Fakat hareket ve varlık sensörleri genellikle harekete duyarlı olarak çalıştıkları için, uzun süre hareketsiz yapılacak olan bir çalışmada içerideki varlığı tespit edemeyecektir. YAKB de yapılan çalışmada, sistem odası içindeki gaz, alev, duman ve sıcaklık sensörlerinin birinden yüksek değer okunduğu an, alarm ve resimli mesaj sisteminin devreye girmesi sağlanmıştır. Yetkili kişi kendine gelen resimli mesaja bakarak sistem odasının durumunu görebilmektedir. Ek olarak Android veya Web tabanlı uygulama sayesinde yangın söndürme sistemini uzaktan devreye alabilmektedir. Yurtdışından temin edilen termal varlık sensörü devreye alındığında, maksimum 1 m^2 alan içinde etkili çalışabildiği görülmüştür. Pahalı olması ve zor temin edilebildiğinden dolayı, sisteme termal varlık sensörüne ek olarak IP kamera da eklenmiştir. Böylece manuel olarak kontrol yapılması sağlanmıştır.

AYS'nin üçüncü bölümünü GKB oluşturmaktadır. Sistem odasına saat 17:00 den sonra girilmek istendiğinde, tuş takımı veya parmak izi kontrollerinden biri ile giriş yapılması sağlanmıştır. Tuş takımı ile üç defa yanlış giriş yapıldığında ya da AYS'de tanımlı olmayan bir parmak izi üç kez okutulduğunda, giriş hakkı sonlandırılarak alarmın devreye girmesi ve yetkili kişilere kısa mesaj atılması gerçekleştirilmiştir. YAKB bölümünde kullanılan IP kamera bu bölümde de tanımlanmış olup, kısa mesajı alan kişiler tarafından görüntüleme yapılabilmektedir.

AYS'de çalışan tüm gömülü kartlar, dışarıdan batarya veya adaptör yardımı ile beslenmektedir. Bu cihazların elektrik ihtiyacını karşılamak için Elektrik Elektronik Mühendisliği bölümünde bulunan güneş panelinin kullanılması öngörülmüştür. Bu panelin daha verimli kullanılabilmesi için gömülü kart kullanılarak tasarlanan güneş takip sistemi (GTS) geliştirilmiştir. Bu GTS yardımı ile güneş panelinin yatay eksenli olarak güneş hareketlerini takip etmesi sağlanmıştır. Sistem odasının montaja uygun olmayan fiziksel konumu dolayısıyla, geliştirilen GTS bölüm binasının üzerinde çalıştırılmaktadır.

Gerçekleştirilen AYS parametrik olup esnek yapıya sahiptir. Yapılan çalışma herhangi bir markaya bağlı kalmaksızın genişletilebilme özelliğine sahiptir. Bu proje farklı binalarda, farklı amaçlar için kullanılabilecektir. Bu tezde gerçekleştirilen tüm tasarım ve deneysel çalışmalar aşağıdaki satırlarda, detaylı bir şekilde sunulmaktadır.

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LIST OF SYMBOLS

b	:	Bias
c	:	Off-set of Polynomial
$\mathbf{c}_h$	:	Vector Stating Center Location of RBF Units
C	:	Trade-off Generalization Ability and Training Error
d	:	Degree of Polynomial Kernel
g	:	Slope of tanh Kernel
h	:	Index of RBF Units from 1 to H
i	:	Index of Inputs from 1 to I
o	:	Output
p	:	Index of Training Patterns, from 1 to P
$u_{i,h}$	:	Input Weight
w_h	:	Weight Value on the Connection between RBF Unit h and Network Output
w_0	:	Bias Weight
$\mathbf{x}_{p,i}$	:	Each Input
$\mathbf{y}_{p,h}$	:	Scaled Inputs
σ_h	:	Radius of RBF Units
γ_h	:	Gamma Parameter of RBF Units
φ_h	:	Activation Function of RBF Unit h
Γ	:	A Training Set
$\mathcal{E}$	:	Maximum Value of Tolerable Error
ξ_i	:	Interval between Actual Values
ξ_i^*	:	Corresponding Boundary Values of $\mathcal{E}$-tube
ω	:	Weight Vector

δ : Width of Gauss Kernel

LIST OF ABBREVIATIONS

3G	:	3^{rd} Generation
4G	:	4^{th} Generation
6LoWPAN	:	IPv6 over Low-Power Wireless Personal Area Networks
AC	:	Alternating Current
AES	:	Advanced Encryption Standard
AI	:	Artificial Intelligence
AIRCON	:	Air Conditioner
AMQP	:	Advanced Message Queuing Protocol
ANN	:	Artificial Neural Network
API	:	Application Programming Interface
ARM	:	Acorn RISC Machine
AS-i	:	Actuator Sensor Interface
ATMEL	:	Advanced Technology for Memory and Logic
ATP	:	Adaptive Tuning Protocol
BACnet	:	Building Automation and Control Networks
BAN	:	Building Area Network
CoAP	:	Constrained Application Protocol
CSV	:	Comma Secured Values
CT	:	Current Transformer
DC	:	Direct Current
DDP	:	Distributed Data Protocol
DDS	:	Data Distribution Service
DPC	:	Data Processing Center
DTLS	:	Datagram Transport Layer Security
DTMF	:	Dual Tone Multi Frequency
EC	:	Extended Coverage

EMS	:	Energy Management Section
EU	:	European Union
FDCS	:	Fire Detection Control Section
G.hn	:	Gigabit Home Networking
GSM	:	Global System for Mobile
HAN	:	Home Area Network
HART	:	Highway Addressable Remote Transducer
HomePNA	:	Home Phoneline Networking Alliance
HVAC	:	Heating Ventilating Air Conditioner
I^2C	:	Inter-Integrated Circuit
ICs	:	Integrated Circuits
ICT	:	Information and Communication Technology
IDE	:	Integrated Development Environment
IEE	:	Institute of Electrical Engineers
IEEE	:	Institute of Electrical and Electronics Engineers
IIOP	:	Internet Inter-ORB Protocol
IPs	:	Internet Protocols
IPSO	:	Internet Protocol for Smart Objects
IPv4	:	Internet Protocol Version 4
IPv6	:	Internet Protocol Version 6
IPX	:	Internetwork Packet Exchange
IR	:	Infrared
ISA	:	International Society of Automation
ISM	:	Industrial Scientific Medical
ITU	:	International Telecommunication Union
ITU-T	:	ITU Telecommunication Standardization Sector
JSON	:	JavaScript Object Notation
Kbps	:	Kilobit per second

KKT	:	Karush-Kuhn-Tucker
KNX	:	Konnex (A fieldbus for building automation)
LAN	:	Local Area Network
LCD	:	Liquid Crystal Display
LED	:	Light Emitting Diode
LF	:	Load Forecasting
LIBSVM	:	An Integrated Software for Support Vector Classification and Regression
LLAP	:	Lightweight Local Automation protocol
LPT	:	Line Print Terminal
M2M	:	Machine-to-Machine
MAC	:	Media Access Control
MATLAB	:	Matrix Laboratory
Mbps	:	Megabit per second
MCU	:	Microcontroller Unit
MLP	:	Multilayer Perceptron
MoCA	:	Multimedia Over Coax
MOSFET	:	Metal Oxide Semiconductor Field Effect Transistor
MQTT	:	Message Queuing Telemetry Transport
NanoIP	:	Nano Internet Protocol
NB	:	NarrowBand
NBP	:	Name Binding Protocol
NEC	:	National Electrical Code
NetBEUI	:	NetBIOS Extended User Interface
NFC	:	Near Field Communication
NN	:	Neural Network
NWLink	:	NetWare Link
PAN	:	Personal Area Network

PC	:	Personal Computer
PCB	:	Printed Circuit Board
PIC	:	Peripheral Interface Controller
PLC	:	Power Line Communication
POE	:	Power Over Ethernet
PPE	:	Personal Protective Equipment
RBF	:	Radial Basis Function
REST	:	Representational State Transfer
RF	:	Radio Frequency
RFID	:	Radio Frquency Indentification
RISC	:	Reduced Instruction Set Computer
RS	:	Recommended Standart
RTC	:	Real Time Clock
RTPS	:	Real-Time Publish/Subscribe Protocol
SBMS	:	Smart Building Management System
SCS	:	Security Check Section
SCR	:	System Control Room
SD	:	Secure Digital
SDK	:	Software Development Kit
SOAP	:	Simple Object Access Protocol
SP	:	Smart Plug
SPI	:	Serial Peripheral Interface
SPX	:	Sequenced Packet Exchange
SQL	:	Structure Query Language
STS	:	Solar Tracking System
SVM	:	Support Vector Machine
SVR	:	Support Vector Regression
TCP	:	Transmission Control Protocol

UART	:	Universal Asynchronous Receiver/Transmitter
UART	:	Universal Asynchronous Receiver/Transmitter
UDP	:	User Datagram Protocol
uIP	:	Micro Internet Protocol
US	:	United States
USART	:	Universal Synchronous/Asynchronous Rec./Transmitter
USB	:	Universal Serial Bus
VSTLF	:	Very Short-Term Load Forecasting
WAN	:	Wide Area Network
Wi-Fi	:	Wireless Fidelity
WPAN	:	Wireless Personal Ares Network
XMPP	:	Extensible Messaging and Presence Protocol

XXXI

1. INTRODUCTION

1.1. Background and Research Motivation

The developing world has caused new needs to arise. Owing to depletion of non-renewable energy sources, more efficient utilization of existing energy technologies has gained significance. With the growth of the Internet and mobile devices, human beings have desired to monitor and manage the objects which they have owned simultaneously.

Conventional devices in the past could be only controlled by using standard buttons such as on and off buttons. Owing to technological breakthroughs, conventional devices have converted into smarter devices. Smart devices can be controlled remotely via the Internet. Due to the increase in the number of devices connected to the Internet, existing IPs (Internet Protocols) named IPv4 (IP version 4) will be inadequate. It is anticipated that this problem will be solved by the arrival of IPv6 instead of IPv4. Thanks to IPv6 which supports 128 bit, all devices which want to connect to the Internet can achieve their connection without any problems.

When energy consumption is investigated on a sectoral basis, it is seen that buildings have a significant place, because commonly use of electrical energy in buildings is unavoidable in today's circumstances. In the investigated studies, buildings consume 40% of annual energy cost in the U.S., and 30% of energy consumption is wasted (Jiechao, 2014), (Costa et al., 2013). The energy consumption of buildings during the whole life cycle is responsible for 40% of total European Union (EU) energy consumption too. In addition, greenhouse gas emissions since buildings account for 36% of EU's total CO2 emissions. Future projections indicate that in 2030 buildings will be responsible for 35.6% of primary energy use in the world, and continue to maintain its importance (Gokce and Gokce, 2014).

According to European standard “EN15232 Energy Performance of Buildings-Impact of Building Automation” building automation systems can, depending on building type and equipment standard, produce the following potential energy savings: restaurants 31%, hotels 25%, offices 39%, shopping centers 49%, hospitals 18%, schools/universities 34% and residential 27% (Gokce and Gokce, 2014).

The European Council outlined clear objectives for the European Union’s 20–20–20 strategy. 20% reduction of the total energy consumption, 20% contribution of renewable energy sources to total energy production and 20% reduction of greenhouse gases are aimed below 1990 emissions before 2020 (Gokce and Gokce, 2014).

Investigations show that, if the building is more than 8-10 years old, the problem is almost guaranteed. Using the smart systems and monitoring all system components to keep under control remotely have been being important to identify these problems in time and to prevent to cause a bigger problem. Simply understanding where and how you use energy can yield up to a 10 percent savings, without significant capital investment.

A substantial share of total energy consumption is due to improper use of appliances, and eliminating this wastage can reduce the overall energy consumption by approximately 30% in buildings (Sharmin et al., 2014). With respect to energy efficiencies of buildings, work by the Danish Technological Institute shows potential energy savings between 10% and 30% by adjusting the different sensors and control settings (Heller and Orthmann, 2014). Similarly, in the studying, which is done Costa and his friends, the potential to save energy by systematic building management is known to be significant and estimates range from 5% to 30% (Costa et al., 2013).

A study which is done by Nyguen and Aiello in 2013 has been supported by data. The simulation results show that occupancy-based control can result in 10–40% in energy saving for Heating Ventilating Air Conditioner (HVAC) system.

Up to 40% of the lighting electricity could be saved by systems such as daylight harvesting, occupancy sensing, scheduling and load shedding (Nguyen and Aiello, 2013).

In this thesis, development of smart systems is aimed for using in the building. Smart building is a general name of smart systems in buildings. According to building type and location, this name can be called different forms like smart homes, smart data processing center, smart residential buildings, smart commercial buildings, and so forth. Before introducing details of the realized studies, it will be much better to summarize the general phenomena.

1.1.1. Smart Systems and Control Methods

Depending on the development of technology, the need for energy has also increased. Furthermore, measurement, monitoring, analysis, and management of appliances' energy consumption should be kept under control 24/7 continuously. Therefore, the requirement for controlling the behaviours of such appliances has led to the emergence of "smart" concept. In the recent years, the smart concepts such as smart phone, smart home, smart building, and smart city have attracted the researchers interested in this area. Moreover, with the advancements in the Internet of things (IoT), almost all conventional devices will be smarter. In the every sector that is needed, smart systems, can be implemented. Most application areas of smart systems are energy, waste water, transportation, buildings, homes, mobility, public services and city management.

Measurement, monitoring, analysing and management of energy consumption in buildings is crucial to prevent from inefficient use of energy. To measure is to know. Knowing is everything. If the measured values check and take precautions, energy saving will be obtained easily. Not only energy saving is obtained but also energy efficiency consciousness will increase.

Many smart appliances are frequently employed in the energy market. These devices can be bought and installed easily. This is not a problem. The most important problem is the installation of the old conventional devices. The installation of the new smart device is simpler than incorporating the old device into the smart system. Conventional devices should be converted into the smart devices.

If a system has microcontroller, sensor, and actuator at the same time, it can be defined that this system is smart. For becoming a smart system of any system it should be possessed these three components. Main components of a smart system are shown in Figure 1.1.schematically.

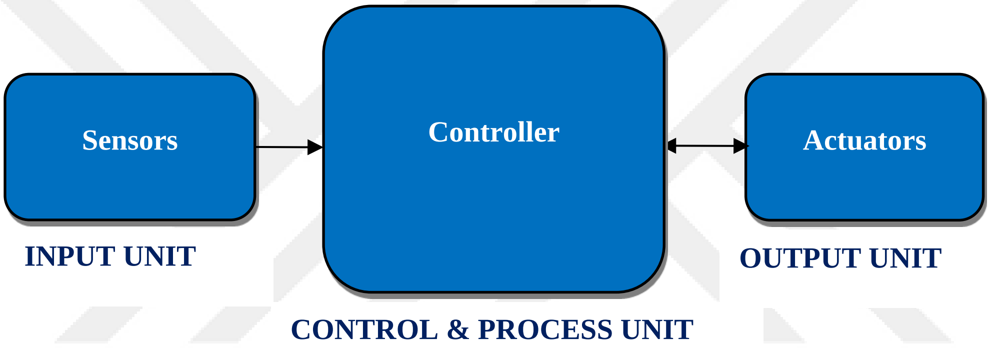


Figure 1.1.Main components of a smart system schematically

Sensors sense values which will be measured and send these values to the microcontroller. The microcontroller reads data which comes from sensors and send command the actuators. Actuators manage (open or close) the system according to coming data from the controller. At the result of the actuator movements, values which sensors sense and send to the controller will change. The controller compares this changed value to the set value and sends a new command to the actuator. This process will continue until a current value is equal to the set value (Akhras, 2000).

Control process which is done by the controller may be three types as automatically, manually and remotely controlled (Suryadevara et al., 2014). Manual control is harder than the automatic control for controlling of any system.

It is almost impossible to achieve the desired value manually. Even if the simplest automatic control system is used, this simple control system will be better than the manual control. In Figure 1.2., the water temperature control system has been shown.

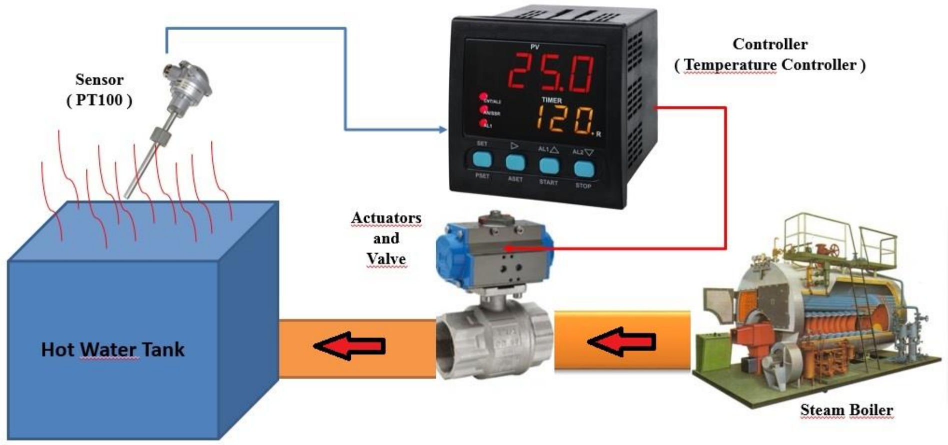


Figure 1.2. Hot water temperature control system

The working principle of this system is quite simple. PT100 temperature sensor senses the water temperature and send to the controller as the resistance value. According to coming resistance value, temperature controller learns temperature value and compares this values to the set value. If the current value is lower than the set value, it sends to open command to the actuator. When the actuator takes the open command, the valve will be opened more. When the valve opens more, steam amount which goes into the hot water tank will increase and thus water temperature will be increased automatically. In summary, this process will continue until current value is equal to the set value.

In this thesis, new smart applications were developed and implemented in the real locations. In realized applications, all control methods were used together. Manual control was used in ON/OFF control in desktop applications. Automatic control was used in all project steps. Finally remote control methods were utilized in the web and Android based applications.

1.1.2. Embedded Cards and Arduino

After the invention of the integrated circuits, a new era has begun with the design of embedded systems. Nowadays, embedded systems and microcontrollers (MCUs) have been prevailed in almost all electronic devices. The most widely-used and well-known embedded systems in the literature are Raspberry Pi, Panda Board, Beagle Board, Parallax Basic Stamp, Arm, Basic Micro, and Arduino. Particularly, Arduino and Raspberry Pi have been used in a number of academic studies and commercial applications. Various microcontrollers have been installed in different embedded systems. Peripheral Interface Controller (PIC), Acorn RISC Machine (ARM), National Electrical Code (NEC) and Advanced Technology for Memory and Logic (ATMEL) are the most preferred microcontrollers. ATMEL MCUs are chosen by Arduino. Programming languages such as Python, Perl, BBC basic, C, Delphi and similar languages can be used in order to write codes to these MCUs.

In Pham’s study (Pham, 2014), performances of sending and receiving data for selected embedded cards which communicate by 802.15.4 ZigBee protocol have been investigated. Imote2, Mega, Telosb, Arduino, Waspmote, and Micaz boards have been examined in detail. The main goal of this study is to determine which board has the best performance. All boards have been tested with intensive data such as image and sound data. As a consequence of measurements, the communication delay time values shown in Figure 1.3 for a 100-byte packet. As illustrated in Figure 1.3., although arduino and waspmote boards are faster than the others at in sending data, they are slower than the others at in reading data. While sending throughput values are 10 ms and 11 ms for Arduino and Waspmote, reading throughput values are 35 ms and 50 ms respectively. According to measured delay times, the best performance belongs to MicaZ.

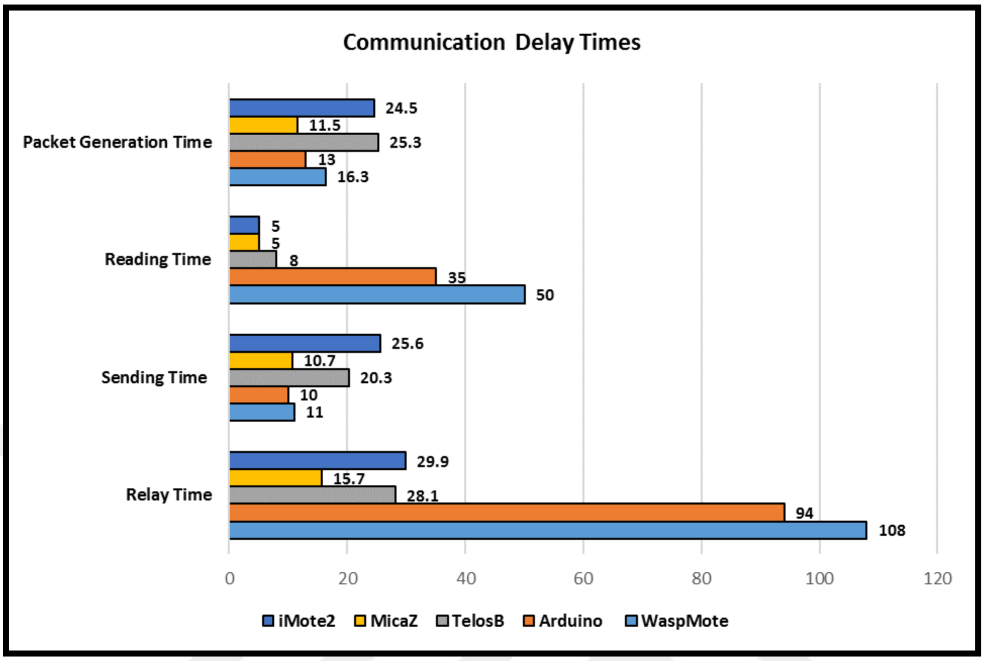


Figure 1.3. Communication delay times of some embedded cards

When the previous studies are investigated, it is seen that the most used cards are Arduino and Raspberry Pi respectively in academic studies. In Turkey markets, almost all Arduino cards can be obtained easily. When Raspberry Pi compares with Arduino, it is second order. There are a lot of sample applications which are realized by using Arduino in literature. Because Arduino has many advantages, it has been chosen in this thesis.

Arduino boards are classified into four main sections as “Entry Level”, “Enhanced Features”, “Internet of Things” and “Wearable” boards in Table 1.1. Entry Level boards are for beginner users. Enhanced Features cards have been used in more professional applications. In this thesis, Arduino Mega card has been preferred. IOT cards are for Internet and remote connection applications. Finally, wearable cards are used for applications which Ardunio boards can be sewn to clothes. Wearable cards are especially used in health and security applications (Nayyar and Puri, 2016; Cvjetkovic and Matiyevic, 2016; Arduino.cc)

Table 1.1. The classification and comparison of Arduino Boards

Category	Board Names	Processor	Operating Voltage (V)	Input Voltage (V)	CPU Speed (MHz)	USB	UART
Entry Level	Uno	ATmega328P	5	7-12	16	Reg	1
	Leonardo	ATmega32U4	5	7-12	16	Mic	1
	101	Intel® Curie	3.3	7-12	32	Reg	-
	Robot	ATmega32u4	5	-	16	Reg	1
	Esplora	ATmega32U4	5	7-12	16	Mic	-
Enhanced Features	Mega	ATmega2560	5	7-12	16	Reg	4
	Zero	ATSAMD21G18	3.3	7-12	48	Mic	2
	Due	ATSAM3X8E	3.3	7-12	84	Mic	4
	Mega ADK	ATmega2560	5	7-12	16	Reg	4
	Pro	ATmega168	3.3	3.5-12	8	*	1
		ATmega328P	5	5-12	16		
	M0	ATSAMD21G18	3.3	5-15	48	Mic	1
	M0 Pro	ATSAMD21G18	3.3	6-15	48	Mic	1
Internet of Things (IoT)	Yun	Atheros AR9331	3.3	5	400	Mic	1
		ATmega32u4	5		16		
	Ethernet	ATmega328P	5	7-12	16	Reg	-
	Tian	Atheros AR9342	3.3	5	560	Mic	1
		SAMD21G18	3.3		48		
	Industrial 101	Atheros AR9331	3.3	5	400	Mic	1
		ATmega32u4	5		16		
	Leonardo Eth.	ATmega32u4	5	7-12	16	Mic	1
Wearable	Gemma	ATtiny85	3.3	4-16	8	Mic	-
	Lilypad Ard. USB	ATmega32U4	3.3	3.8 - 5	8	Mic	-
	Lilypad Ard. Main Board	ATmega168 / ATmega328V	2.7-5.5	2.7-5.5	8	*	-
	Lilypad Ard. Simple	ATmega328	2.7-5.5	2.7-5.5	8	*	-
	Lilypad Ard. Simple Snap	ATmega328P	2.7-5.5	2.7-5.5	8	*	-

“Regular" abbreviated as "Reg" and "Micro" also abbreviated as "Mic"
* These cards are connected to Future Technology Devices International (FTDI) cable

Table 1.1. Continue

Category	Board Names	Analogue Input / Output	Digital Input / Output PWM	EEPROM Capacity (KB)	RAM/SRAM Capacity (KB)	Flash Capacity (KB)
Entry Level	Uno	6 / 0	14 / 6	1	2	32
	Leonardo	12 / 0	20 / 7	1	2.5	32
	101	6 / 0	14 / 4	-	24	196
	Robot	6 / 0	20 / 6	1	2.5	32
	Esplora	-	-	1	2.5	32
Enhanced Features	Mega	16 / 0	54 / 15	4	8	256
	Zero	6 / 1	14 / 10	-	32	256
	Due	12 / 2	54 / 12	-	96	512
	Mega ADK	16 / 0	54 / 15	4	8	256
	Pro	6 / 0	14 / 6	0.512	1	16
				1	2	32
	M0	6 / 1	20 / 12	-	32	256
	M0 Pro	6 / 1	14 / 12	16	32	256
Internet of Things (IoT)	Yun	12 / 0	20 / 7	1	16,000	64
					2.5	32
	Ethernet	6 / 0	14 / 4	1	2	32
	Tian	6 / 0	20 / 12	-	64,000	16,000
					32	256
	Industrial 101	12 / 0	20 / 7	1	64,000	16,000
					2.5	32
	Leonardo Eth.	12 / 0	20 / 7	1	2.5	32
Wearable	Gemma	1 / 0	3 / 2	0.5	0.5	8
	Lilypad Ard. USB	4 / 0	9 / 4	1	2.5	32
	Lilypad Ard. Main Board	6 / 0	14 / 6	0.512	1	16
	Lilypad Ard. Simple	4 / 0	9 / 5	1	2	32
	Lilypad Ard. Simple Snap	4 / 0	9 / 5	1	2	32

All Arduino boards have digital input/output pins and analog input pins. Whole digital inputs can be also used as digital output at the same time. Some of digital outputs pins can be utilized as PWM (Pulse Width Modulation) to obtain an analog output signal. The number of PWM is different for every board. For example, while the number of PWM is 15 for Mega, the number of PWM is only 6 for Uno. PWM is a method for the gaining analog output signal from the digital output. Digital output has 5V High value or 0V LOW value worth. PWM voltage can be adjusted by setting the delay time of low and high values of digital output. Thanks to this PWM voltage, lamp light can be dimmable or motor speed can be increased or decreased easily and can be realized similar experiences.

Arduino boards can communicate with the help of serial communication protocols. They can be connected to a computer with USB (Universal Serial Bus) port. Arduino software codes defined as "sketch" can be written by using Arduino IDE (Integrated Development Environment) which has Arduino language resembling C. In Addition, Arduino boards also support some other communication protocols such as UART (Universal Asynchronous Receiver Transmitter) TTL (Transistor Transistor Logic), I^2C (Internal IC) / TWI (Two Wire Interface) and SPI (Serial Peripheral Interface). Serial communication is suitable for data transferring between boards.

UART is a kind of serial communication protocol. All boards which have UART port use to Digital 0 and 1 pins physically. These pins are used for transmitting data (TX) and receiving data (RX). The transmitting data pin of the first card connects to the receiving data pin of slave card. Similarly, the receiving data pin of the first card connects to the transmitting data pin of the second card mutually. Because of this cross connection, UART communication can be implemented between only two devices at the same time. UART is asynchronous since the communication doesn't rely on a synchronized clock signal. UART communication can be used by helping of Serial and Softwareserial libraries. Almost all Arduino boards except Lilypad wearable cards have TX and RX pins and support the UART communication protocol. UART connection diagram is shown in Figure 1.4.

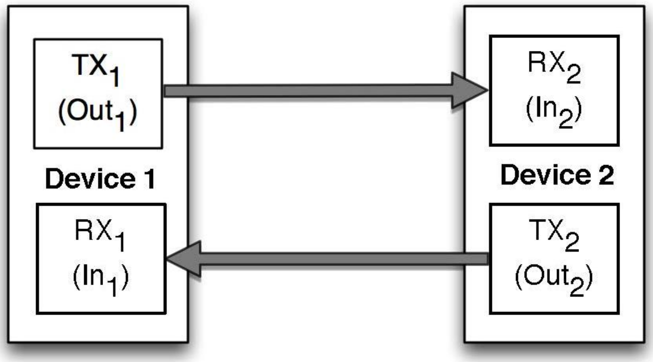


Figure 1.4. UART connection diagram

I^2C requires two wires and some resistor for connection as shown in Figure 1.5. Therefore, it can be named TWI which stands for Two Wire Interface. This protocol was developed by Philips. I^2C can be used for communication between boards or other devices with provided Wire library (wire.h) and using Serial Data (SDA) and Serial Clock (SCL) lines. I^2C buses can typically reach speeds up to 400 Kbps (Iyer, 2016).

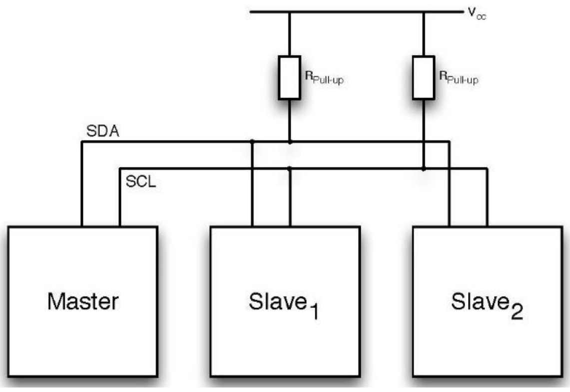


Figure 1.5. I^2C connection diagram

SPI protocol was developed by Motorola. SPI is mainly used for connecting boards with various shields as it provides very fast communication. (Iyer, 2016; Cvjetkovic and Matiyevic, 2016). There are two types of devices in SPI. First device type is master and the second device type is slave. Master is a main device and slaves are managed by the master device. SPI connection diagram that has only single slave is shown in Figure 1.6. Similarly, Multiple-slaves can be connected to a single master as shown in Figure 1.7.

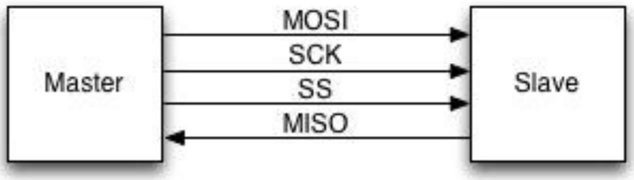


Figure 1.6. SPI connection-A single slave connected to a single master

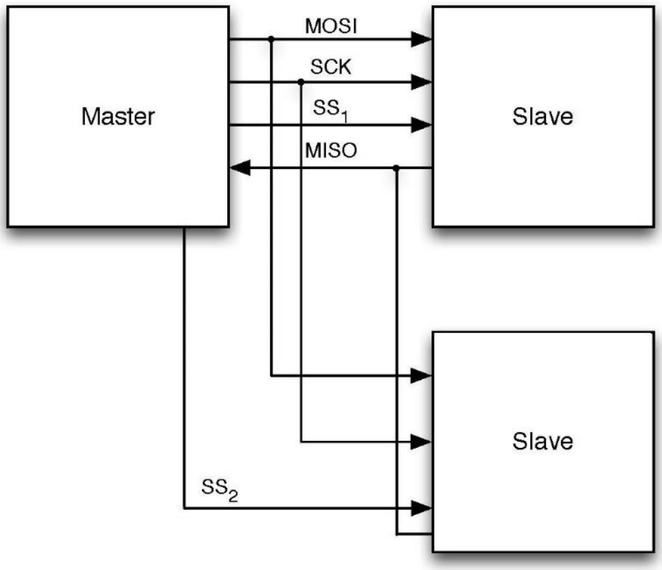


Figure 1.7. SPI connection-Multiple-slaves connected to a single master

1.1.3. Communication Protocols and ZigBee

While the devices communicate with each others, they need to communication protocols. As people who speak different languages do not understand, devices that use different communication protocols don't understand each other. All appliances should use the same language to communicate with each other. While a device is connected to another device or all other devices, network structure named as network topology should be established.

There are four major network topologies shown in Figure 1.8. The simplest network topology is named "pair" topology. It can be called "peer to peer" by some computer users. One of the two devices is router or end device and the other is coordinator node. Devices can be communicated each other as face to face. The second topology is called "star" because of its view. In this topology, coordinator node is located in the center of the all other nodes. Because the coordinator node is connected to all other nodes directly, finding of fault location and finding of solutions is easier than other network topologies. Every packet has to visit the coordinator node at center. The third topology is named "cluster tree". At this topology, devices named as nodes are communicated with each other hierarchically. Coordinator node is located on the top of the tree structure. That's coordinator is at the peak point. End nodes and routers are the lower steps. The nodes at the different regions are communicated each other via coordinator node. The last topology is called "mesh" topology. This topology is similar to cluster tree topology. The coordinator node manages all network and also routes packet messages between all end devices and routers. At this topology, if the path of the packet is not defined then system investigates and finds the shortest and fast path to sends by using this path (Foglia, 2012; Arslan, 2009).

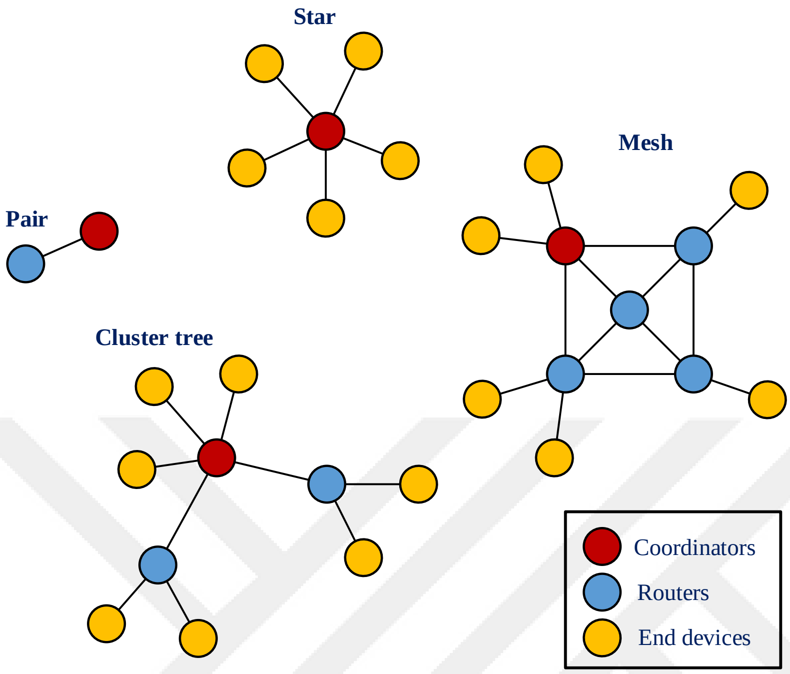


Figure 1.8. Network Topologies

Devices used in smart systems can be communicated by wired or wireless methods. The most used wired communication methods are RS232, RS422, RS485, USB, and ETHERNET. In addition to these methods, electricity grid can be also used for transportation of data. Thus, the extra cost of wiring avoids automatically. These systems are named as power line communication. In places where wired communication is not suitable, wireless communication methods can be used. The most used wireless communication methods are NFC (Near Field Communication), RF (Radio Frequency), GSM (Global System for Mobile Communication), 3G (3rd Generation), 4G (4th Generation), BLUETOOTH, WI-FI (Wireless Fidelity) and ZigBee. IEEE has set different standards for ZigBee, Wi-Fi, and Bluetooth. At these technologies, PHY (Physical) and MAC (Media Access Control) layers are defined. 6LoWPAN is developed for IPv6. It has low power consumption for communications. Z-Wave is a special solution for some applications (Mahmood et al., 2015).

Comparative study of ZigBee, Wi-Fi, Bluetooth and 6LoWPAN reveals that Wi-Fi has advantages of larger coverage and wide-spread availability, Bluetooth is easily accessible and provides secure short range communications, 6LoWPAN adds IP functionality to WPANs and consumes low power while ZigBee accommodates much more nodes, operates at low power and requires low cost (Mahmood et al., 2015). Researches show that the most used wireless protocols are Bluetooth, Wi-Fi and ZigBee. When they are investigated detail, everyone's has advantages and disadvantages against each other. In Table 1.2, the comparison of ZigBee, Bluetooth, and Wi-Fi has been shown (Huang et al., 2011).

Table 1.2. Comparison of ZigBee, Bluetooth, and Wi-Fi

	ZigBee	**Bluetooth**	**Wi-Fi**
IEEE Standard	802.15.4	802.15.1	802.11 a/b/g
Maximum signal rate	250 kb/s	1 Mb/s	54 Mb/s
Nominal range	10-100 m	10 m	100 m
Max. number of nodes	>65000	8	2007
Power consumption	Low	Very Low	High
Protocol complexity	Simple	Most Complex	Complex
Cost	Low	Low	High

ZigBee/IEEE 802.15.4 is wireless technology which can be communicated bidirectional featured with short range, low cost, low power consumption. It has a lot of advantages when it compares with the other wireless communication methods. Advantages sides of ZigBee / IEEE 802.15.4 can be summarized as low power consumption, low data rate and low cost. The battery which has low power consumption is installed in ZigBee devices. These devices which run with ZigBee communication protocol has low data rate about 250 Kbps. Because of low rate and simplicity of this protocol stack, it has low cost. When it compares with the other communication protocols, ZigBee is the cheapest. This protocol supports as many as 65,535 devices per network.

ZigBee protocols can be used pair, star, mesh and other networking structures. Especially, mesh networking allows for reliable data transfer and it is flexibility in networking with multiple topologies. Data integrity verification and authentication are realized by using 128-bits AES (Advanced Encryption Standard) encryption algorithm at the MAC layer. ZigBee doesn’t require any license for the wireless communication. Data which has 2.4 GHz Industrial Scientific Medical (ISM) band and 250 Kbps data transmission capacity can be moved between 10 meters and 70 meters. Devices which communicate with ZigBee protocol in latest emerging technologies can be communicated until approximately 40 kilometers (Arslan, 2009; Batista et al., 2013; Jin, 2011; Sakhare and Deshmukh, 2012). Comparison of different ZigBee modules is shown in Table 1.3.

Table 1.3. Comparison of ZigBee modules

	XBee ZB	**Xbee-PRO ZB**	**Xbee-PRO 868**
Indoor Range	40m	90m	550 m
Line of Sight Range	120m	1500 m / 3200 m	40 km
RF Data Rate	250 kbps	250 kbps	24 kbps
Frequency	2.4 GHz	2.4 GHz	868 MHz
Transmit Power	1.25 mW/2 mW	10 mW/63 mW	1 mW/315mW
Encryption	128-bit AES	128-bit AES	128-bit AES
Number Channels	16	15	1
Transmit Current	35 mA/45 mA	205 mA	500 mA
Receive Current	38 mA/40 mA	47 mA	65 mA
Topology (Suggested)	Mesh	Mesh	Star
Estimated Price	$17	$28	$69
Regions	Europe, USA, Australia, Canada,Japan	Europe, USA, Australia, Canada, Japan	Europe

When the ZigBee controller delay time compares with Wi-Fi controller access delay time in lighting switch control, ZigBee has less delay time. While ZigBee controller access delay time is about 670 ms, Wi-Fi Controller access delay time is approximately 1337 ms. similarly, when access controller delay time at radiator valve compares with each other, ZigBee has a shorter time. ZigBee controller access delay time value is too short to be measured and recorded by the current test equipment. At the same situation, Wi-Fi controller access delay time is about 613 ms.

In this thesis, a novel architecture for a households and building automation system was proposed and implemented, using the relatively new communication technology ZigBee. ZigBee protocol was used for communication. The most important reason of the use of ZigBee wireless protocol instead of other protocols was cheaper, reliable, and stable than the others. The aim of this Project is to establish the cheapest and most quality system.

In a similar study to realized project, the potential for successful co-existence and interoperability of Wi-Fi and ZigBee has been practically proven with implementation with a real building automation system by Gill and his friends in 2009. Focus group sessions have shown a positive attitude towards the developed system and significant support for the diverse modes of control, monitoring, and integration with existing home networks such as Wi-Fi (Gill, 2009).

In this thesis, Realized project were studied by using both wired and wireless protocols (hybrid system) ZigBee supported desired all devices will be added to our system by rearranging software lines easily. Realized system has flexible structure. Without being bound to any particular brand has expandable structure. Realized Project will be able to used different type buildings for different purposes.

1.2. Scope of the Thesis

The subject of the thesis is “Design and Implementation of a Wireless Sensor Network for Energy Monitoring, Analysis and Management in Smart Buildings”. Monitoring, analysis, and management of energy consumption of buildings are vitally important for prevention of inefficient energy usage. Because of this, appliances which consume energy should be monitored 7 days 24 hours continuously. Measured values in the studies should be saved. In addition, saved data should be analyzed by statistical and machine learning methods. As a result of this analysis, energy efficiency and amount of the energy saving should be increased by the developed smart algorithms. The system block of the planned project has been shown in Figure 1.9.generally.

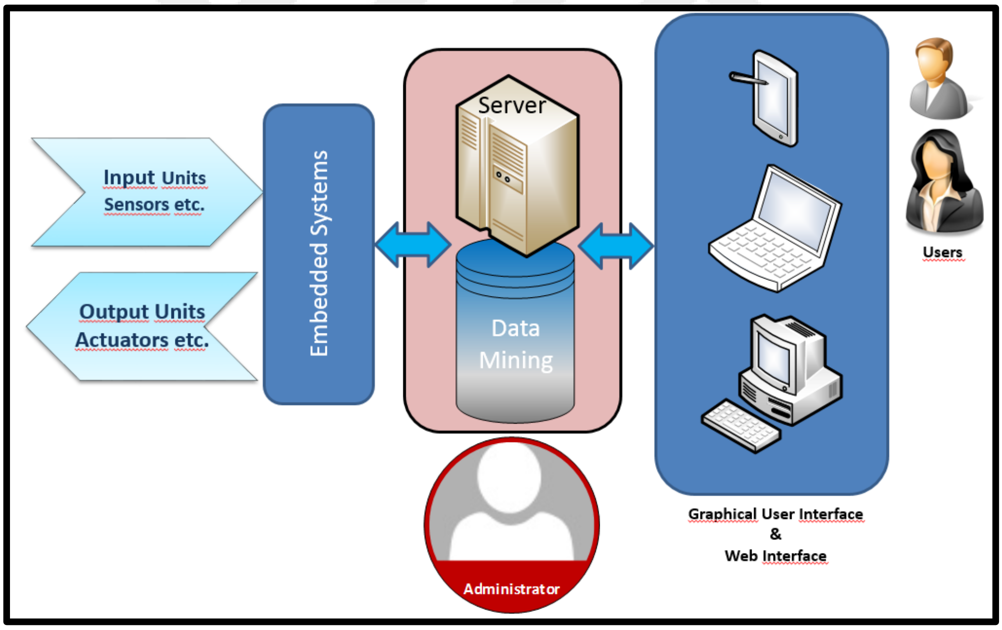


Figure 1.9. Block diagram of the realized project

This study mainly consists of three main parts. These parts can be named as embedded system part, administrative part, and client part. Embedded system part occurs from input devices, output devices, and microcontroller. Second part named administrative part occurs from server computer and desktop management software. Finally, third part named client part occurs from users and desktop, web, and Android based software solutions. After the hardware installation, MCUs were programmed by Arduino IDE. Arduino IDE software was used to write codes for microcontroller with ATMEL integrated circuit. When the microcontroller software completed, server established to connect between the microcontroller and Android software. Windows Server 2012 R2 operating system was established to Server Computer. Furthermore, Firebird database software was installed on the Windows Server 2012 R2 opearating system. Server management software was written by using Delphi compiler. This software helped to the administrator to adjust all parameters. The server application is like a bridge between plug and users. Moreover, desktop and web based software were written for users at the client side. Finally, the Android based application was written for the users by using Delphi compiler. All systems and the working principles of the parts of systems have been given as following lines.

This thesis consists of three sections which are energy management section (EMS), security check section (SCS), and a fire detection control section (FDCS). The combining of the systems were named as Smart Building Management System (SBMS). Previously, standard software algorithm was evolved to be used in all sections. Thanks to this algorithm, the requirement of separated software was abolished for different sensors, actuators, and other devices.

In the EMS, studies were actualized interested in SP, split type air conditioner, lighting control, and solar tracking system generally. Smart algorithms were written for maximum performance with minimum energy. In addition to EMS, SCS, and FDCS were occurred in the thesis. In the SCS, fingerprint reading, password entry with keypad, timing control with Real Time Clock (RTC), and SMS sending applications were realized. Finally, in the FDCS, fire detection, MMS sending, IP camera control, and fire extinguishing (if desired) applications are carried out.

In this thesis, smart systems were established by ARDUINO electronic card. ATMEL microprocessor on the Arduino card was programmed by C+ compiler. Thus, the connection between sensors and actuators was provided. Arduino cards which are used as end devices were connected to router cards with using ZigBee wireless protocol. Similarly, Arduino cards used as router devices were connected to coordinator card with using the same wireless protocol. Users were able to access to SBMS via desktop, web or android applications. The study in this thesis is shown in Figure 1.10.schematically.

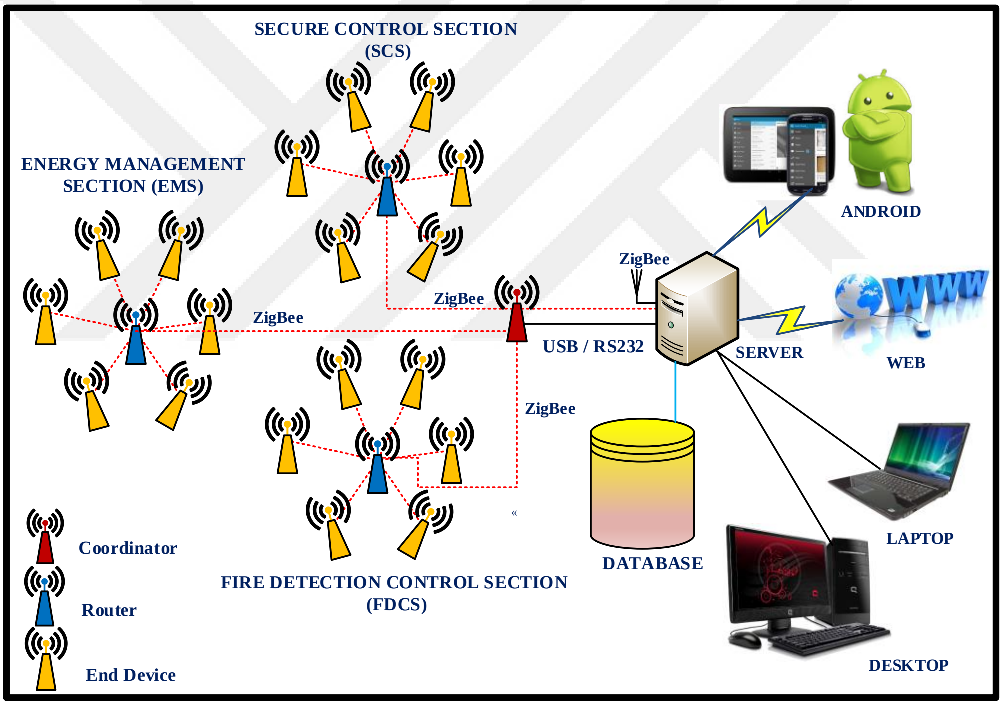


Figure 1.10. Schematic view of thesis project

ZigBee wireless communication protocols are supported one of the pairs, star, cluster tree, and mesh connection types or more than one without any problems (Foglia, 2012). From the end devices to router devices are connected with a star topology. After that, from the router devices to coordinator device is also connected with a star topology. Thus, trouble-free operation of the system is provided. As a result, the combining of star connections occurs mesh connection. The connection of the coordinator card with the main computer named server is provided by wired such as USB, Ethernet or wireless such as ZigBee, Wi-Fi. Generally, The ZigBee coordinator has connected through the USB cable of the host computer, which stores the data into a database of the computer system. USB connection provides more speed than the Wireless Connection. Connecting to routers of end devices and connecting to coordinator nodes of routers with different methods are realized Javaid and his friends. In their study, the lowest energy consumption is provided between 20 Kbps and 250 Kbps frequencies (Javaid et al., 2012).

In this thesis, computer software programs were developed for monitoring of the established Arduino cards, storing data, and management of all systems. These software applications were operated at three different media as desktop, web, and mobile. After physical installation and coding of embedding cards are done by using the Arduino Integrated Development Environment (IDE) software with C+ programming language, a Windows based desktop application operating on the server computer has been developed for reading data on these cards, storing the read data, analyzing the stored data, reporting, and management. Created software by using Delphi programming language is the main software program of SBMS. All cards and all parameters belong to these cards were identified by using this software program. Furthermore, all of the obtained data were stored via this software program in a database file on the same server. FireBird database was chosen for being open source, free, and compatible with Delphi. The software of the server was not only used for all identifications and parameter settings by people who have a high level of administrative authorization but also held all data and reports that users can access at the same time. Users can remotely access and control devices by connecting to server software. Users can either connect to SBMS via desktop application or different applications developed for web-based or mobile devices. Instead of using separate languages for user platforms, the Delphi compiler, which can be converted to an Android-based application by making minor changes in the desktop application, has been chosen as the programming language. Additionally, the application has been turned into web-based by Thinfinity VirtualUI software of Cybele Software after some small revisions. Hence, users can govern devices at the remotest point according to their pre-defined authorizations in the system via three different graphical interfaces in order to access SBMS and database. Obtained data from measurement and monitoring in the SBMS were analyzed by using artificial neural networks (ANN) methods, the most efficient utilization of energy has been provided at the most appropriate time by load forecasting.

In the EMS, smart plug design was designed. The energy consumption of devices was measured by smart plug and measured values sent to software program at the main server. The design of smart plug was actualized by utilizing Arduino microcontroller. Especially to prevent electrical accident and save human health, smart algorithms were developed for smart plugs. Thus, risk of the electric shock was minimized. Thanks to smart plug, the energy consumption of devices could be measured. The design of smart plug was done by using Arduino MCU. Voltage, current, frequency, and cos φ values were measured. Power consumption amount was calculated by using these measured values. Afterwards, all measured and calculated values were stored in the database. As a result of storage, obtained data were analyzed by Artificial Neural Network (ANN) and/or statistical analyses methods. Thus, important critical values and parameters for the using of energy were identified. After that, energy was used as most efficient at the best time.

In the EMS, in addition to smart plug design, the study interested in the management of split type air conditioners were also performed secondly. 3 pcs air conditioners in the Balcalı Hospital Data Processing Center (DPC) were operating at the same time without any criteria. In this study, according to temperature and humidity values, these air conditioners were run sequentially. That’s why, the use of more energy than needed were prevented. Thirdly, basic lighting control system was developed in the EMS. In this section, LED dimming was achieved according to movement and the direction of movement. Thus, unnecessary lighting of corridor and DPC was blocked. Finally, in the EMS, STS was developed to use for power supply of the embedded cards.

In the SCS, fingerprint reading, password entry with keypad, timing control with Real Time Clock (RTC), and SMS sending applications were realized in order to prevent unauthorized access to DPC.

In the YDCS, fire detection, MMS sending, IP camera control and remote access control, and fire extinguishing applications are carried out. In this section, the fire-extinguishing section was depended on manual control of the authorized person. In the existing DPC, since DPC has no automatic fire-extinguishing system except manual fire extinguisher tube, this control was provided as only relay control.

In short summarize, in this thesis, a smart building management system (SBMS) was developed to utilize in households and buildings. This system could communicate wirelessly. Arduino MCUs were used as embedded system cards. C+ software language was used for writing codes in Arduino. The exception of the embedded system codes, desktop, and Android mobile applications were developed by using Delphi programming language. What is more, the web application was obtained by compiling Delphi desktop software with the Thinfinity VirtualUI software of Cybele Software after some small revisions. Realized projects are flexible structure. According to users' preferences, sections can be converted to desired features with small adjustments.

As a result of the realized thesis project, new, cheaper, self-learning and energy analysis, monitoring, management software which run on different platforms such as desktop, web, and android were designed and implemented. Design and implementation of the SBMS has been presented in the following section with all the details.

1.3. Objectives and Disposition of the Thesis

The objectives of this thesis are as follows:

- To describe smart systems such as smart households and smart buildings and describe the control methods of smart systems,
- To describe communication protocols related to wireless communication protocols such as ZigBee and Wi-Fi,
- To describe embedded cards related to Arduino and the other similar cards.
- To present literature review on smart systems related to smart buildings, smart homes, smart households, and smart plugs especially,
- To summarize literature review on embedded systems related to Arduino and similar other embedded cards with ATMEL microprocessors. Especially, studies interested in energy saving and energy efficiency were preferred,
- To present literature review on IoT and to summarize literature review on communication protocols related to wireless protocols such as ZigBee and Wi-Fi especially,
- To develop a new standard software algorithm for Arduino embedded cards and to write MCUs software codes,
- To establish wireless network between end devices and router devices and then establishment of wireless network between router devices and coordinator device,
- To evaluate hybrid operation of wired and wireless networks,
- To establish the energy monitoring, analysis, and management system named as SBMS that consists of EMS, SCS, and FDCS.
- To design and implement of EMS,
    - To design and actualize smart plug by using Arduino card,
    - To design and implement air conditioner controller system,

    - To design and perform lighting dimming system,
    - To carry out STS for evaluating of alternative energy sources,
- To design and implement SCS,
    - To design and implement keypad to enter password,
    - To design and perform fingerprint reading system,
    - To design and control unauthorized entry control system,
    - To establish SMS sending infrastructure,
    - To establish warning systems,
- To design and operate FDCS,
    - To design and implement fire detection system by using temperature, smoke, flame, and carbon monoxide sensors,
    - To establish to take photos and MMS sending infrastructure,
    - To run IP camera and add it to SBMS
    - To prepare the infrastructure of automatic fire extinguishing system.
- To establish database server,
- To establish wired network between database server and coordinator device and assessment of wireless network in detail,
- To write desktop management software with Delphi,
- To convert from desktop application to web based management software by Thinfinity VirtualUI software of Cybele Software after some small revisions,
- To write android monitoring software with Delphi after some small revisions and adjustments,
- To save all measured and calculated values to tables of database,
- To forecast future values by using statistical and machine learning methods on the stored data,
- To report all needed and desired information

1.4. Contributions of the Thesis

This thesis project provides following original contributions to the research and application area of smart systems;

- When the previous studies are investigated, it is seen that separate software programs have been developed for each embedded card. In this thesis, all of the embedded cards are classified into two groups with respect to the purpose of use. As a consequence of the classification, a single software program code for each class has refined for standardization. If there is a need for add new cards to the system later, one of the standardized code lines will be loaded and executed according to the intended use of the card. The standardized code and load over an embedded card with a limited resource have been lightened by transferring to the server. The limited resources that embedded cards have are too small in comparison with the resources that advanced computers have. This study is the first of its kind in the literature when similar studies in the past are investigated.
- In this study, smart plug was designed. Thanks to smart plug, the energy consumption of devices were measured easily. The design of smart plug was realized by using Arduino microcontroller. Voltage, current, frequency and cos φ values were measured directly. Power consumption amount could be calculated by using these measured values. When the previous smart plug studies are investigated, it is seen that cos φ value is predicted or taken power factor value in main distribution electrical panels. In this thesis, cos φ could be measured simultaneously and according to this read value, power consumption amount could be calculated at the same time.
- Used applications in commercially have been written by abroad source. Few applications written in Turkey are based on desktop generally. The realized project was one of first domestic software with Desktop, WEB and

Android editions. Inefficient use points of electricity were identified and produced solutions specifically. Generally, existing programs communicate the unidirectional. The planned software will be communicated bidirectionally. Realized software was used for both monitoring all devices that measure all system components and managing of the actuators.

- In existing systems, the consumption of each component has been investigated individually itself. In this project, the effect of one component to the other components will be investigated and smart algorithms were developed. Finally, it was investigated how the change in one component affected another component.
- The software and the control systems used commercially generally are complex and expensive. Big businesses have used PLC and SCADA systems. Small businesses could not buy these systems due to its expensive. Planned software and system are cheaper and simpler usage than these systems. In addition, this software has user-friendly interfaces.
- In this thesis, according to proposal project, scenario and room numbers, device numbers, sensors, and actuators can be calculated automatically. As a result of this calculated values, network topology and initial cost can be determined by SBMS. Thus, cost analysis has been realized for people who will invest to new projects.

1.5. Outline of the Thesis

The content of the thesis is arranged as follows:

After an introductory section where smart systems, control methods, communication protocols, and embedded cards are defined, the background and research motivation of the study are given, the scope, objectives and disposition, and contributions of the thesis are introduced, the structure of this thesis is as follows:

In Chapter 2, literature survey studies on smart systems, embedded cards, IoT, and communication protocols from 2010 to 2018 are presented especially. Under the sub-sections, the latest literature including research articles, conferences, e-books, handbooks and company reports interested in Arduino, ZigBee, energy efficiency, energy saving and energy management systems are summarized.

In Chapter 3, after wide literature survey, the general information on SBMS and new algorithm which are developed for Arduino MCUs are presented in detail.

In Chapter 4, design and implementation of the EMS are presented systematically. Newly developed SP, split type air conditioner control system, lighting control system, and solar tracking system are explained.

In Chapter 5, design and implementation of the SCS are presented gradually. Fingerprint reading, password entry with keypad, timing control with Real Time Clock (RTC), and SMS sending applications are explained in detail.

In Chapter 6, design and implementation of the FDCS are performed step by step. Fire detection, MMS sending, IP camera control, and fire extinguishing applications are explained in detail.

In Chapter 7, the conclusions, contributions of the thesis and author’s recommendations for future work are explained.

Finally, all the references used in the thesis, biographical information of the author and sections of the Appendices are presented.

2. REVIEW OF RELATED LITERATURE

In the literature review section, studies published in the last few years and related to embedded systems, smart systems, and the Internet of things (IoT) subjects have been reviewed. Especially, theses, journal articles and conference publications published in IEEE, IEE, SCIENCE DIRECT digital libraries, and PROQUEST Dissertation and thesis database have been investigated. In the all studies, energy efficiency, energy saving, energy monitoring, energy analysis and management subjects are priorities. While investigating embedded systems, microcontroller cards such as Arduino, Rasberry Pi, and Waspmote have been reviewed in detail. In addition to embedded systems, in the literature review of smart systems, smart buildings, smart homes, and smart plugs are also reviewed. Along with the progress of technology, IoT concept has been started to use instead of the smart concept. Instead of writing smart words in front of all devices, the concept of IoT has been derived. Finally, studies interested in IoT have been reviewed comprehensively and summarized thoroughly.

While literature survey is conducted, it is seen that smart systems, embedded systems, and IoT studies are inseparably related to each other. Due to this relation, one, two or all of them can be seen at the same time in the literature.

Under the following sections, the latest literature including research articles, conferences, e-books, company reports, web pages, MSc and PhD theses related with the topic of this thesis are summarized in detail.

2.1. Review of Smart Systems

Generally, smart systems are used in buildings for energy efficiency, fire detection, and safety systems. In this thesis, projects interested in these three subject were realized. Smart and computer-aided automatic control systems should present more comfortable life to residents and the other living creatures. Nowadays, smart systems have been strengthened by using machine learning algorithms. Thus, developed systems can be managed by using self-learning methods. In addition to machine learning systems, smart systems can be monitored and managed by remote access and management tools in mobile phones, laptop computers, and other mobile devices.

There are a lot of studies interested in monitoring, analyzing and optimization. One of the best studies is realized by Gokce and Gokce in 2014. They have developed a new energy monitoring, analysis and optimization tool for energy efficient buildings. Their study can be grouped by four sections as data mining and monitoring, data analysis, user awareness and optimization. Java programming platform is preferred to develop software at their study. When it is focused on energy efficiency section, three main sections are attracted attention as energy consumption monitoring, the heating system controlling and lighting system controlling. As a result of their study, their system achieves to improving building performance, developing intelligent control routines and implementing fault diagnosis measures (Gokce and Gokce, 2014).

In the smart building, smart plugs which provide the electric power are very important to follow and check the electricity consumption. In addition, to prevent electrical accidents is also very important. When the smart plug doesn’t use, electricity should cut automatically to prevent accident and wasted energy. In the study on smart plug performed by Parka and his friends, a power extension cord with 3 outlets has been designed by them. Every plug has different priorities. Maximum power consumption which is consumed by plugs can be set and when exceeding of maximum power, according to the priority order, energy of the plugs can be cut off order. The energy of plug which has first priority will be cut off latest and the latest priority plug will be cut off first. In addition, if desired, starting time and finishing time can be defined in their program. Thus, working time range of plugs is also defined (Parka et al., 2013). In this thesis study, smart plugs and energy analyzers will be used to measured consumptions of energy. In addition to devices on markets, the new smart plug will be designed. Especially, special smart plug will be developed to prevent electricity accidents.

Similarly, Shajahan and Anand have improved a smart plug by using Arduino and Android systems to monitor energy consumption of electrical devices (Shajahan and Anand, 2013). They have used Arduino Duemilanove board as a microcontroller and ENC28J60 ethernet module is preferred for Internet connection. Moreover, SCT-013-030 Current Transformer (CT) is utilized for measuring current value of the electrical device. In addition to hardware requirements, Arduino Integrated Development Environment (IDE) software is used for programming of Arduino board. Android Software Development Kit (SDK) and Eclipse SDK softwares are employed for programming android software. Furthermore, Megunolink open source software is utilized to plot obtained current values. In the realized study, CT is connected to an air conditioner for testing and current values are acquisited. Apparent power values and average power values are calculated by using the acquisited current values. After the testing, developed smart plug with CT is connected to electrical devices and an inverter is implemented to the smart plug. Electrical consumptions of the connected devices are measured for eight hours and three nights consecutively. As a result of the realized measurements, unwanted loads are switched off and the measurement continued. Due to the closed devices, energy saving around 15% is acquired after three days (Shajahan and Anand, 2013). In this study, measured devices are not exactly certain and unwanted devices are not clearly specified.

In the study of (Santis et al., 2016), Santis and his friends have proposed smart monitoring system to monitor low voltage (LV) electrical grids. The proposed project has been tested at four different cases. In the proposed scenario, real-time measurements have been obtained. Measure current and voltage transducers are connected to Arduino DUE controller to measure three-phase line currents and voltages. In this scenario, current and voltage values of the grid lines are measured phase by phase in every 0.5 second continuously. These measured values are compared to real values measured by using Fluke 287 multi-meter. As a result of this comparison, maximum less than 1.30% differences are reported. According to measured current and voltage values, active and reactive power values are calculated. Wi-Fi and GPS module are also used in the proposed scenario at the same time. GPS module is used for location of the measurement point and Wi-Fi is used for communication. All measurements and calculated values are displayed on a web page. One of the advantages of this system is that it can be seen from anywhere by web browser easily. Another important advantage is the low cost of devices. The entire system only costs €200 approximately.

In 2014, Hussein and his friends realized smart home prototype for disabled people (Hussein et al., 2014). In the proposed project, all systems are almost backed up. Two internal networks are used for connection among devices used in the disabled people's house. One of them is used to ZigBee protocol and other is used to Power Line Communication (PLC) protocol. Normally, the system runs by using ZigBee but if any problem occurrs, PLC network will be substituted automatically. Similarly, two external networks are used for communication between responsible people and proposed system in the house. Thanks to these external networks, remote access to the system can be provided by the authorities. In their experiments, Neural Networks (NNs) methods have been used to predict future events. Firstly, in their smart fire detection system, perceptron based feed-forward neural network has been used. Five parameters have been used as input parameters. These parameters are carbon monoxide level, oxygen concentration, smoke detection, heat level, and flame detection. With the helping of these parameters, they will be able to determine if there is a fire or not and according to changing values of parameters, they will be able to guess fires which can be occurred. Another NN study is interested in users' habits and forecasting their movements. This NN type is a recurrent neural network. In this study, Arduino microcontroller is used for switching ON/OFF of devices such as coffee machine, television, lights, and so forth. As a power measurement device, a differential amplifier circuit is also used. Used NN methods, Arduino controller and other electronic circuits like differential amplifiers have been operated in relation to each other. For example, if someone wakes up in the morning, when he/she goes into the living room, prediction mechanism will be started by NN methods. Because of this, the lights of the room and television will be turned on automatically.

Behan and Krejcar have realized web-based smart home system. In their paper, they have described the common problem of house automation system primarily. According to them, this type of home automation system has closed based solutions which means there is not certain standard for sensors, controllers, and user interface development softwares. They have proposed a new type infrastructure based on both software and hardware side is open sourced. In this project, Linux based open source minicomputer RaspberryPi is used as home controller named as commander and arduino which has similar features with RaspberryPi is used as room controller. Ethernet shields which have Power over Ethernet (POE) feature are used instead of the using external power supply in the proposed project. At the same time, another duty of ethernet cards is to provide communication among the devices. In their solution proposal, the physical house is divided into logical units. Every logical unit is equivalent to a room or a part of a house. Every logical unit has its own controller which connects to commander via Unshielded Twisted Pair (UTP) cable in a star topology. Data is transmitted and received over ethernet and all device powers are supplied by PoE standard named as 802.3af by The Institute of Electrical and Electronics Engineers (IEEE). The power of PoE depends on supply voltage and it is confined with a maximum of 48 V or 400 mA. After the installation of hardware, web-based management software can be used through any mobile device that has Android, IOS or Windows operating system. In summary, they have realized web-based controlled smart home automation system based on open electronic and open-source software solution in this project. This new system will provide a connection between sensors and web interface with controlling, monitoring, and visualizing. The most important innovation of this study is that the implemented system can be redesigned, improved, upgraded, or tuned by anyone under an open-source license.

2.2. Review of Embedded System Cards and Arduino

Arduino and the other embedded cards have broad application areas such as energy, health, industry, safety, transportation and so forth. Many studies in recent years are investigated meticulously and papers published between 2010 and 2017 are primarily chosen. All of these studies interested in smart systems directly or indirectly. Some investigated implementations have been given as follows.

Gad and Gad have developed a new temperature data acquisition system for solar energy applications. When this system is compared to classical data acquisition systems, the newly developed system has a lot of significant advantages. The main advantages of the system are its cheap and flexible structure. Because of the flexible structure, used temperature sensors can be changed with other type and mark sensors easily. In this study, by using 16 temperature sensors and taking 5 minutes sampling rate, ambient temperatures were measured and recorded on Secure Digital (SD) memory card with Comma Secured Values (CSV) file format. In classical systems, recorded data on Arduino or other embedded system boards wait until system operator or administrator downloads data to a computer. When data are downloaded into the computer, recorded data are transferred to computer from the embedded system board. The operation of described) system is quite simple. By the new technology, sampling rate defines recording time periods and measured temperature values can be saved on the SD card without the need of any computer with CSV file format. A new CSV file is created and recorded on SD card every new day. Starting and ending time values are defined in the system by using the PIC and demonstrated on Liquid Crystal Display (LCD) screen. Used Arduino board on this system is responsible for evaluating of voltage values and writing data on the SD card. LM35DZ analog temperature sensor is used on the sensor-based designed card. It can measure temperature values between -55°C and +150°C. Its accuracy is 0.25% of the real value. Its internal temperature is about 0.1ºC. In this study, both PIC and Arduino MCUs are programmed respectively. PIC software consists of three sections named as initialization, waiting and recording. Starting and ending times of recording time are defined in the initialization section by users. During the execution of the software, the starting and ending times are compared with Real Time Clock (RTC) until the RTC is smaller than the ending time. Data packet is defined in PIC software and sent to Arduino board (Gad and Gad, 2015).

Arduino software is responsible for the proper communication between PIC and Arduino. Arduino software checks the number of bytes in the data packet from PIC to Arduino. If data packet is corrupted, Arduino software will cast it away and wait for a new healthy packet. If data packet is not corrupted, it will be transferred from PIC to Arduino. Arduino software runs also similar. It also consists of three sections, namely initialization, waiting and storing. Initialization section is responsible for defining all hardware components such as Universal Asynchronous Receiver/Transmitter (UART) unit, input output pins. UART is a serial communication port utilized in all Arduino boards. It is used to establish a connection between Arduino and the other devices such as personal computer (PC), laptop computer and tablet computer. Initialization section of Arduino software checks the SD card firstly. If the SD card is not connected or malfunctioned then program will be terminated. All sensors are controlled by fifteenth and sixteenth bytes of the packet. According to these numbers, temperature data coming from the sensors are stored to the SD card with respect to the sensor number. If desired, these data can be transferred to desired devices such as computer and other storage devices (Gad and Gad, 2015).

In another study that is realized by using Arduino, Barro-Torres and his friends. They used to determine whether if personal protective equipment (PPE) is worn or not. If a personal don’t wear PPE, the conducted project gives warning alarm. In the study, mesh topology is used as shown in Figure 2.1. The use of protective equipment is vital to prevent accidents at work. Some of the most important working rules on a building site are related to the use of protective elements, such as helmets, gloves, boots, harness, etc. These elements are collectively known as personal protective equipment (Barro-Torres et al., 2012).

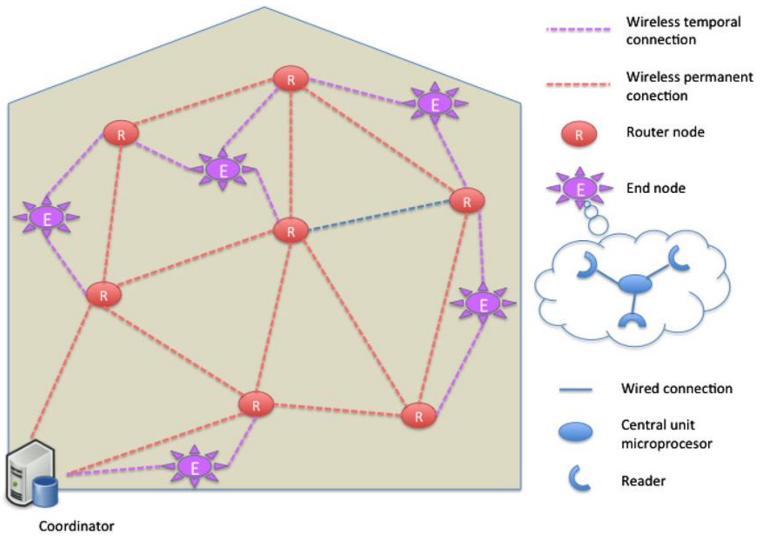


Figure 2.1. System architecture scheme

In order to perform such a control, an architecture composed of a wireless local area network and a body area network is considered. A system prototype was developed by using ZigBee and Radio Frequency Identification (RFID) technologies that support the deployment of both kinds of networks. End nodes as shown in Figure 2.2 represents workers. As illustrated in Figure 2.2., RFID devices on the workers are shown whether workers use personal protective equipment (PPE) or not. In order to provide occupational safety for occupational health, using of PPE is vital. In addition to preventing PPE accident formation, when an accident occurs, it protects person's health. Most people ignore or forget to use PPE. Because of this situation, automatic control with MCU instead of manual control should be preferred.

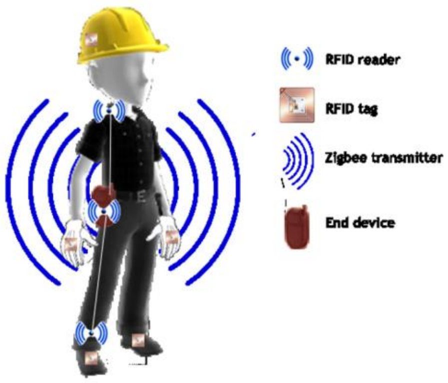


Figure 2.2. Defining of a worker as an end node

An architecture composed of two kinds of network, which consists of a mesh network and a Building Area Network (BAN) was presented. The mesh network is needed to transmit information gathered from devices worn by the workers. These devices, called end nodes, make use of a BAN, in order to distribute several personal protective equipment detectors in the worker's clothing. In order to build a prototype, Torrez and his friends have considered ZigBee technology for the mesh network and RFID for the PPE detection system. In the study, a detailed description of the system, consisting of an architecture of the system, the hardware design of the end nodes and a software protocol has been presented (Barro-Torres et al., 2012).

In 2016, Kumar and Solanki utilized Dual Tone Multi Frequency (DTMF) module for turning on and off all devices in a building environment remotely (Kumar and Solanki, 2016). According to them, when a user calls the building by using his/her mobile phone, another mobile phone in the building with an active automatic reply mode accepts the call and DTMF module converts the corresponding frequency value of the pressed key on the user's phone to a voltage value and sends the voltage value to the Arduino UNO board. After receiving the voltage value, Arduino sends this signal to the ON/OFF relays. Thanks to the relays, user defined appliances can be either switched on or off. For instance, by pressing key 1, remote desktop can be turned on. Similarly, IP camera can be also turned on by using key 3. By the activation of all devices, the user can connect to the building's remote computer via the Team viewer software on his/her own computer. Once the connection is established, IP camera and the mobile robot can be controlled by using windows based software program written in Visual Studio. Arduino UNO board and RF Transmitter card are used for the control. Four servo motors are utilized for step by step control of the IP Camera. As a consequence of this project, a home monitoring system with low cost is developed. This system can be especially used for observing disabled persons or others such as infants, children or someone requiring care.

In the study of (You et al., 2014), with the help of Microsoft Kinect sensor and Arduino controller have developed a control system for ambient lights and sounds. Therefore, they have developed C# windows application software to recognize full body movements. Firstly, user gestures, body movements, and facial expressions are recognized by using Microsoft Kinect SDK. Then, according to recognized user face, user identification is determined. After the user is determined, owing to user gestures, light, and sound system control commands are sent to Arduino controller. Afterwards, Arduino processes these commands and switches on or off light and music systems by using Arduino's relay shield. Consequently, 95% movement sensing success has been achieved by this study. In this study, they experienced movement detection problem. In order to solve this problem, machine-learning techniques are proposed for future studies.

In literature survey, (Rahman et al., 2015) were realized Smart Energy Meter by using Arduino and GSM module. Owing to this smart meter, they have measured energy consumption and calculated the electricity bill. Firstly, they have simulated this study in Proteus and then conducted in a laboratory environment successfully. In this work, they have used energy meter Integrated Circuit (IC), Arduino microcontroller, GSM modem and Arduino relay shield. After power on, Arduino has turned on the relay and connects the load and energy meters to the line. Energy meter sends an impulse to Arduino according to energy consumption. So Arduino increases the value and shows on its display. At the same time, GSM modem checks whether there is a new SMS or not. And then if the SMS text is "DATA", it sends consumption data measured by the Arduino and it stores in EPROM to electric provider company. If the text is "LINE CUT", GSM modem sends command to Arduino to turn-off relay and deenergize the line energy. In contrast, if the text is "LINE OK", Arduino turns on the relay again and the load will be connected to line. In this study, they have calculated 1 kWh consumption for every 1600 impulse by using energy meter IC. A Light Emitting Diode (LED) is connected to Arduino to show the impulse visually, so the LED flashes with each impulse. If the provider company wants to read consumption value from the meter, they can send a SMS to a smart meter. Afterwards, smart meter has replied to taken message by sending the consumer ID and consumed energy value. (Rahman et al., 2015) can also control the line status. This project can be turned on or off the line energy which customer connects by using GSM wireless network protocol. One of the disadvantages of this system is high material cost. It may be reduced by mass production. In this study, the authors show that realized smart energy meter saves from time, money, human power, and labor costs.

In 2014, handwriting recognition system was used by (Lian et al., 2014) to define user identity and to open or close the door. The handwriting samples of system users are saved to the system database. When a user connects to Wireless Fidelity (Wi-Fi) network of the realized project and logins to the mobile application of the smart home system, handwriting recognition software are launched. After the login process, the software determines if the user is valid or invalid. If the user is invalid, the system is shut down and this user is kept out of the system. If the user is valid, the user is redirected to handwriting recognition screen to check one's own handwriting. When a user writes a word that was stored in the database before, the system compares the written word to stored word in the database. If the comparison is true, door security screen is opened. With the help of this screen, open or close command is sent to Arduino microcontroller. Arduino manages the relays for locking or unlocking the door. After the completion of door opening or closing, the user is logged out of system automatically. In this project, Arduino controller is only used for digital Input/Output (I/O) control.

Ismail and his friends have developed a door lock Android application named “LockIt Door” for disabled people in their study (Ismail et al., 2014). This application has been designed by using Eclipse and Java softwares. This study has been especially realized for disabled people who use a wheelchair. The disabled users can use Android application without any human help easily. In this realized project, bluetooth communication protocol is preferred instead of Wi-Fi, ZigBee, NFC, and others. The working principle of the implemented circuit can be briefly summarized as follows; written Android application connects to arduino controller through bluetooth module. According to command coming from the android software, the relay contact which is connected to arduino either opens or closes door. In order to find an effective range of bluetooth, the realized project has been tested for three different environments such as indoors with obstacles, indoors without obstacles, and outdoors without obstacles. After these tests, maximum range radius has been found as 20 meters without any problems at outdoor without obstacle area. Wi-Fi communication protocol can be used instead of bluetooth to improve the effective range in the future works.

Wang and Chi have designed a new temperature and humidity measurement circuit which can communicate wirelessly (Wang and Chi, 2016). The designed system consists of two parts. In the first part, temperature and humidity sensor named DHT11 is connected to the Arduino controller which has a wireless transmitter. In the second part, arduino controller that has a wireless transmitter is connected to LCD, buzzer and setting module. As understood from the devices, the first part is used for input and second part is used for output. Read values with the helping of the first part is sent to the second part with the helping of wireless. Wireless modules communicate with each other by serial communication protocols. Taken values are employed in the second part and displayed on the LCD screen. In this project, normal temperature and humidity are defined by using potentiometer named as setting module in the project. If the range values are exceeded or fell down, the buzzer will be active. According to Wang and Chi, it is an advantage that this project consists of two parts. Because the location where the sensors are located and the location where the results are displayed may be different. The realized project has been tested for the indoor and outdoor environment. While wireless communication is provided up to 40 meters in an outdoor environment, the maximum effective range is up to 20 meters in the indoor environment because of the barriers. As a result of this study, the advantages of this system can be summarized as low cost, low power consumption, high accuracy, and so forth.

(Ramadhani et al., 2013) have designed a web-based air quality monitoring system that can measure and display the types of gases like carbon monoxide and sulfur monoxide. In the realized prototype, gas sensor has been developed by (Ramadhani et al., 2013). Zinc Oxide thin film is used as a gas sensor material in order to for measuring the amount of gas. Monitoring system mainly consists of head and body modules. While head module has a gas sensor, arduino board, and ethernet shield, body module has server and database. In this study, gas sensor is used for sensing of the amount of gas, ethernet shield is used for communication and arduino microcontroller is used as Analog to Digital Converter (ADC). In addition, server and database are used for data acquisition and data management. The implemented system runs briefly as follows: when designed gas sensor perceives the amount of gas in the environment, the resistance of gas sensor will change. These resistance values will be analog input values of arduino. Arduino will convert these analog values to the digital values and then digital values will be transferred to the server through the ethernet shield. Data which arrive the server will be saved to the database as raw data by using simple PHP (Personel Home Page) interface. This process will continue periodically. The whole raw data will be converted to understandable data by software and graphical plot diagram. Besides, all data will be saved to MYSQL database tables. Consequently, the users can monitor graphic and gas values by using this web-based software easily. In the realized prototype, in order to increase system sensitivities, the amount of the carbon dioxide added into the sensor material should be used for different concentration.

2.3. Review of Internet of Things and Communication Protocols

In our continuously developing world, communication technologies are one of the most critical elements of development in technology. The technologies which are commonly used for communication are not only important for today's world, but also for near future, the period from now on. The key to the communication technologies is protocols/standards which is approved of and described by the international institutions such as Institute of Electrical and Electronics Engineers (IEEE), ICA, ISO/IEC. By the use of protocols and standards, people have been able to communicate with each other by using these technologies. However, nowadays not just people use communication ways, there are also things that do use communication protocols and standards to communicate with each other without no human interaction at all. Even though the setup of the systems must be done by authorized individuals, the operating processes are able to be worked by itself thanks to the brand new type of communication technology that named as Internet of Things (IoT).

In IoT concept, all of the electronic equipment should be managed to communicate with each other by using such protocols/standards in a common network field. The main point of this operation is the rightful choice of communication protocols, and how to use them between the related devices. At this point, it must be understood that the choice of which protocol will be used is very important and also hard because there are a lot of procotols and standards in communication fields. Therefore, it is expected that this paper will benefit researchers who are interested in related areas by providing an insight into communication and network protocols/standards and by explaining these protocols with a proper detailed table. The communication protocols are listed in one table content and listed in three different main categories as shown in Figure 2.3.

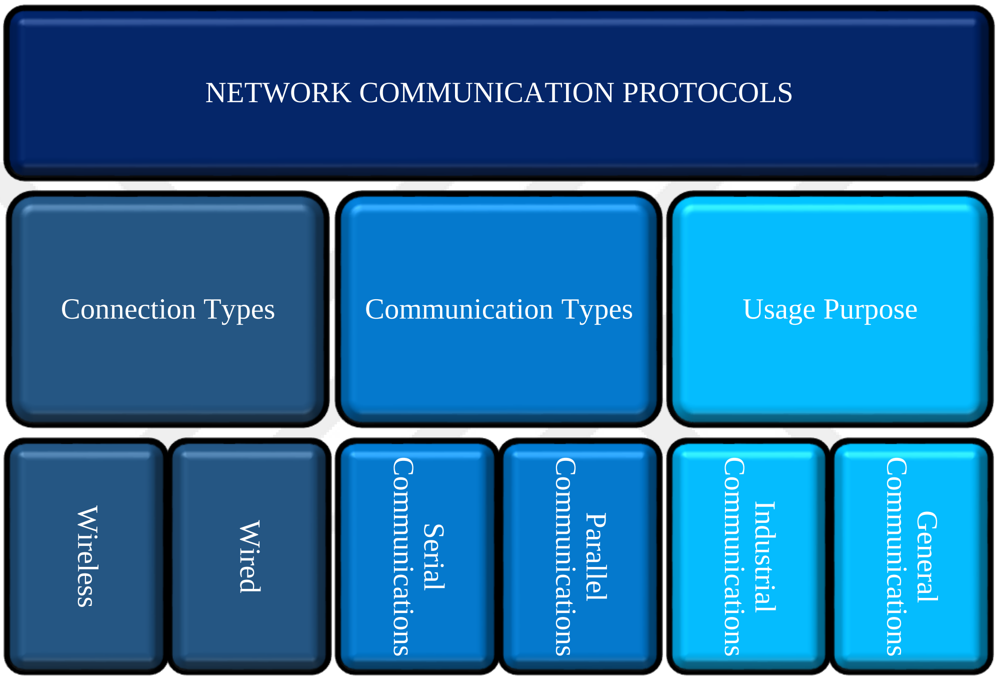


Figure 2.3. Network communication protocols

As shown in Figure 2.3., Network communication protocols consist of Wired/Wireless Communication Protocols, Serial/Parallel Communication Protocols and Industrial/General Communication Protocols. These categories have also sub-categories related to them. Overall protocols have been explained in the following lines.

In our consistently developing world, it is clear that the technology will never stop and keep on improving what it consists of by contributing the existing knowledge. Before this new era of technology, which meant the fourth industrial revolution called Industry 4.0, people had been dealing with limited production and manufacturing techniques and knowledge. However, it will be harder to analyze the up-to-date information into processes from now on. That is because of the unpredictable increment on this new kind of improvable technologies directly related to the communication protocols. Thus corporates have no choice to operate with the actual techniques and knowledge about these concepts into their production and manufacturing processes not to fall behind in the market. In order to keep up with where the industry goes, it should be attracted attention to numerous communication standards and network protocols as mentioned in this paper.

2.3.1. Background of IoT

The vision of Information Technologies is only expected around the traditional desktop computers at first by a large majority in the sector. However, it did not take long to clearly understand that with the developing Internet technology, the IT market cannot stand still the same for long years. The idea of connecting all devices to each other was probably a science fiction topic at those times. A part of the community is still in agreement with this new concept back then in the 1970s. The main idea which was first called as “embedded Internet” or “pervasive computing” is turned into a general term as IoT thanks to a British pioneer Kevin Ashton (Ray, 2017).

The concept did not evolve to today’s form at once. As it is stated that it has been developing, like an evolution itself, since the time that two different located machine communicated with each other by using more primitive communication technologies, like the telegraph technology. Besides this technology, the electromagnetism and radio waves have later become more effective for new kinds of communication technologies, which consists of the most popular one, RFID standing for Radio Frequency Identification. As clearly seen that the term has been evolving continuously due to the increased needs and requirements. The point of mentioning these terms that all of these works are steps of the much wider concept named IoT. There will be more positive sides of using IoT, instead of the previous communication technologies. The detailed opinions about the foresight of IoT are also highlighted in this paper.

IoT and its applications have advantages for especially future social life, such as smart lighting, smart transportation or smart health applications. Even now people are using such applications every day. There is one big difference between these kinds of apps and the promising apps of near future. The most observable point of today's applications is connecting two devices with each other by using Bluetooth or such M2M (machine-to-machine) communication protocols. However, there will be billions of devices in the world a few decades later from now on. At that point, it will be a huge complexity. To figure out this capability problem, the concept of Internet Protocol version 6 (IPv6) has been developing for years. It is an important milestone to get rid of the tremendous wide usage of Internet Protocol (IP) for every device in the world. With the help of IPv6 which supports a huge amount of the Internet addresses, exactly 2^{128} or approximately 340 undecillion addresses. It means that every single electronic device can easily be connected to themselves by using the Internet without any IP conflicts for hundreds of years. Other factors that accelerate IoT are mini devices/microprocessors, advanced wireless technologies, increasing bandwidth, and storage power. These side concepts also made it easier to be used.

2.3.2. Techniques and Related Works

Talking about the background of IoT and factors that pushed and helped this concept, it can be noticed that all of this technology has a wide technical side in the background. Even though there are many communication protocols which are arranged according to specific institutional standards, each one of them cannot be used for IoT applications but only several communication protocols are used to achieve its purpose. Therefore, our list of used protocols are limited to a level which is easy to review. Thus the related communication protocols are shown in Table 2.1, the updated table of The Open Systems Interconnection (OSI) Model in IoT, which is referred from (Ray, 2017).

Table 2.1. Updated table of OSI model in IoT

Layers	**IoT Applications and Protocols**
Application Layer	REST API, JSON-IPSO Objects, Binary Objects
Transport Layer	COAP, MQTT, XMPP, AMQP, LLAP, DDS, SOAP, UDP, TCP, DTLS
Internet (Network) Layer	6LoWPAN, IPv6, uIP, NanoIP
Link (Data Link) Layer	IEEE 802.15.4, IEEE 802.11, ISO/IEC 18092:2004, NB-IOT, EC-GSM-IOT, Bluetooth, ANT, Eddystone, ISA 100.11a, Enocean, LTE-MTE
Physical Layer	Devices, Objects, Things

The OSI Model has normally seven different layers inside. These layers are application layer, presentation layer, session layer, transport layer, network layer, data link layer, and physical layer respectively. The application layer, presentation layer, and session layer are considered as just application layer in IoT.

In the remaining part of this section of the paper, the following questions are expressly discussed: What kind of protocols are used for which industrial field, and which protocol has concrete projects in the world. The discussions are based on the example projects of IoT applications which were used for various goals on different locations all across the world. To clearly show the purpose, we made a benefit from such articles which were published in the related fields. Different from the other papers, the detailed table which consists of almost every kind of communication protocols is also shown in Figure 2.4.

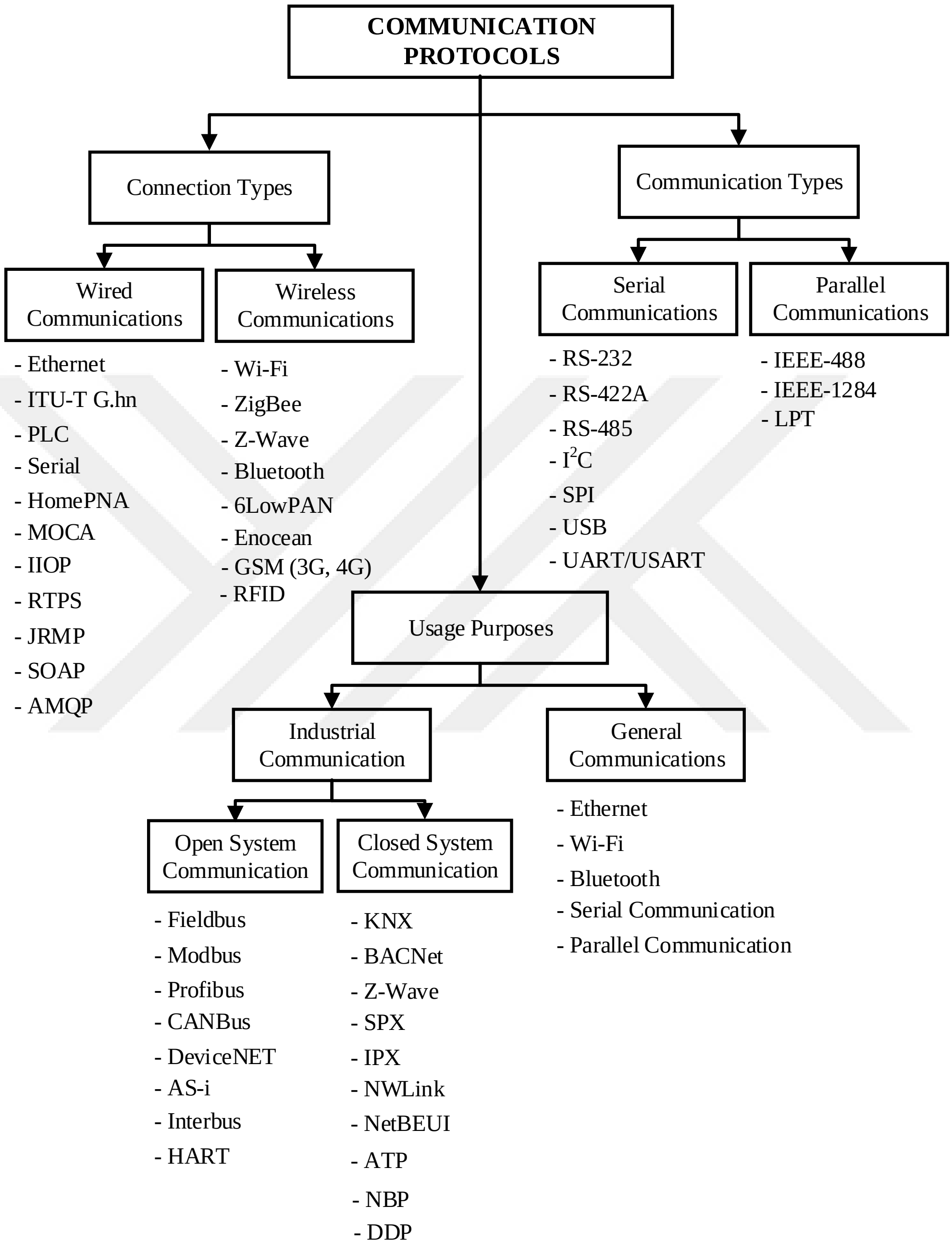


Figure 2.4. Detailed communication protocols

Detailed Communication Protocols figure includes various types of communication procotols in together. All of the communication protocols are categorized properly according to their connection types, communication types, and usage purposes. The table also demonstrates that each protocol has not only a particular category but also another one. For instance, serial communication protocols also take part in Wired Communication Protocols, or Z-Wave protocol is in both Wireless Communication Protocols and Closed System Industrial Communication Protocols.

Besides the wide variety of the IoT environment, one of the main reasons of why this concept has a colossal potential for the future technology is that it has been officially improving for about 16 years by scientists and engineers from all over the globe. As it is said that we have more devices connected to the Internet that the world population since 2011, the number of the connected devices is expected to be around 24 billion devices by 2020 (Gubbi et al., 2013). Most of which devices are already connected to the Internet and its services (Ouaddah et al., 2017).

Communication systems have wide used areas. In a different study, communication with satellite system is preferred by Pimentel at his Doctor of Philosophy in Energy Systems. In this study, the installation of automatic weather conditions station monitoring system is aimed in the arctic region. Power requirements of installed devices can be provided three ways. One of them is to use a generator. At this option, diesel has to be moved to the generator. The second option is to use a battery. At this selection, the changing of the empty battery has to be recharged or changed. Third and last option is to use hybrid systems both local power sources and generator which runs with local power source together (Pimentel, 2012). In this study, the third option is selected and satellite system is used for monitoring of weather condition.

Authors of the related papers and articles summarize the challenges of processes in IoT architectures and applications in the further works.

2.3.3. Main Applications and Opportunities in IoT Related Works

In this section, studies related to IOT, main applications and opportunities were presented. Besides, it has also been focused on application areas of IOT under the following titles.

- **Smart Home**

In recent time, our lives are surrounded by lots of electronic devices such as mobile phones, refrigerators, microwave ovens, televisions, air conditioners, fans, and lights. Therefore some of the IoT applications in the connected home or building network consist of monitoring, security, building automation, remote control, management of energy usage (peak management), smart meters etc. Controlling a home equipment leads to a better home to live in and an efficient energy management. So the consumers also become more involved in the IoT revolution, as the Internet revolution several decades ago (Darianian and Michael, 2008; Stojkoska and Trivodaliev, 2017; Chew et al., 2017; Al-Faris et al., 2017; Bibri and Krogstie, 2017; Reynolds et al., 2017).

- **Industry**

With the fast increment of the 4th Industrial Revolution (which is also called as Industry 4.0) since 2013, not only smart home appliances use IoT technologies but also more complex systems, such as industrial devices installed in plants and factories. The term IoT has been evolved to a detailed another concept named IIoT, which is referred as Industrial Internet of Things. By using these technologies and protocols in plants and factories help to produce power and energy efficiently in a period of time. One of the major advantages of using IoT technology in the industry is to monitor every process continuously. Therefore, the peak times of energy usage or efficient production during time periods can be observed and will be used for future projects (Lu, 2017; Aste et al., 2017).

- **Smart Grid**

In (Mohanty et al., 2016), it is mentioned that energy is the property of an object or system that defines its ability to produce work. One of the main energy sources of our daily lives is the electricity. In the last century, the demand of electricity increased, and is still increasing. By turning the grids into AC from DC helped to reach far locations. However, controlling such an electric grid became harder due to the scattered network structure in long distances. At this point, the smart meters are in. With the usage of these gadgets, we are able to monitor the grid from houses to plants all the time. Not only smart meters but also the production equipment, like power generators, help to use electricity efficiently (Lee et al., 2017; Good et al., 2017; Chiu et al., 2017).

- **Smart City**

After the development of smart devices, the use of these devices in homes and buildings has increased incredibly. .After use of smart systems in home and buildings, similar smart systems have started to use in cities and locational areas. In the studies reviewed, it is seen that studies related to street lighting are involved in the first places. In the street lighting, the control of the lighting systems has played a vital role at least as much as the choice of lighting armature. In the conducted studies, control systems which have different and novel algorithms have been utilized (Chew et al., 2017). With the widespread adoption of smart city concept, smarter cities, sustainable cities, and smart sustainable cities concepts has begun to take its place in the literature (Bibri and Krogstie, 2017). In the urban areas, district level management has begun to prefer instead of the individual smart building management systems. Thanks to district level management, amount of the energy saving has been increased (Reynolds et al., 2017). In a smart city, in addition to smart lighting systems, there are a lot of different subjects such as traffic lighting control, traffic road controls, security cameras, smart waste water management systems, environmental conditions control systems, heating and cooling of public buildings and forth. Because of this, the smart city includes many other smart systems.

- **Transportation**

This concept can be handled with several subconcepts, traffic issues, smart cars, car-parking systems, autonomous cars, fuel management and monitoring systems etc. In (Zanella et al., 2014) it is emphasized that a smart city service should include monitoring the traffic congestion in the city. Even though there are already some camera-based monitoring applications in many cities, more reliable information can be achieved by using fully equipped IoT applications.

- **Health**

According to the related works (Mohanty et al., 2016; Kubler et al., 2017; Duretti et al., 2015) about healthcare applications by using IoT technologies, traditional healthcare is overwhelmed owing to the rapid population growth. Due to limited medical resources and a continuously increasing demand, traditional healthcare needs to be more efficient and sustainable. This is where smart healthcare applications come in. By using smart wearable devices, bio-sensors, information, and communications technologies (ICT), smart hospital and monitoring systems, the future of healthcare is promising (Pramanik et al., 2017).

- **Education**

IoT can also be used to develop our current educational system. In (Merino et al., 2016), it is aimed that taking a contact about the current educational technology trends to suggest a tool that eases the learning process in a STEM, which is Science, Technology, Engineering, Math, educational system (Mäenpää et al., 2017; Corno and Rusis, 2017).

- **Production**

In all of the related papers (Jo et al., 2017; Shah and Yaqoob, 2016; Wang et al., 2016), the concept of smart factory and energy management are considered as the future of production. This is another major usage field of IoT applications since Industry 4.0 has been taking a big role for future production techniques. There are both many virtual applications and field applications of products in different kinds of sectors. The most of them are gathered in energy production according to the related papers. That is because the demand for energy is increasing since the electricity has taken the major parts of our lives. Therefore, we have monitoring, peak management, field equipment and applications currently (Wolfert et al., 2017; O'Grady and O'Hare, 2017).

- **Wearables**

In (Gubbi et al., 2013; Swan, 2012), it is mentioned that the number of connected devices on the Internet exceeded the number of people on the Internet in 2008. And it is estimated to reach billions of devices in the 2020s. This usage field may be the most common field among the others due to the variety of wearable gadgets in the future (Huang et al., 2017). Due to the wearables technology, health problems will be able to follow continuously and critical values will be able to learn before it is too late.

- **Environment**

As it is already seen in the above categories, it is possible for every electronic equipment to be smarter and intelligent. For a brighter future of the next generation, the environment also needs to be intelligent. To get this purpose done, the smart devices are used to measure such environmental values. Some of the application areas are water management, air quality (Zanella et al., 2014), earthquakes, and emergency evaluation (Spalazzi et al, 2014).

- **Security**

Currently, people have many things which can be connected to the Internet all the time, like smartphones, computers, smart cars, smart home appliances, and so on. This is the information era that we live in right now. Even though its lots of positive sides, there are also some drawbacks about connecting every personal device to the Internet. The back door is the security problem. In order to keep the personal information safe, the modern electronic devices need to be equipped with the trustworthy communication protocols and technologies to avoid any kinds of surveillance and security bugs (Garcia et al., 2017; Nguyen et al, 2015; Gandotra et al., 2017; Alaba et al.,2017; Gandotra and Jha, 2017; Hellaoui et al., 2017; Horton et al, 2017).

- **Internet Technologies (IT) & Telecommunication**

These fields of usage are where IoT has mainly focused on establishing a connectivity between all possible electronic devices. Information is the most important subject to be in a variety of constrained networking environment in this era (Guinard et al., 2010). The applied project in IT and Telecommunication constitutes the main purpose of IoT due to its basis is based on communication protocols and standards (Gandotra and Jha, 2017; Khan, 2017).

- **Monitoring**

As it is clearly seen in the related works (Wang et al., 2016; Molina-Solana et al., 2017) which has been reviewed, the purpose of monitoring takes a big slice of the pie chart shown in Figure 2.5, Monitoring aims to analyze and use the data which is collected from the genuine systems. For virtual and digital systems, the related interfaces of the systems need to be monitored remotely from the control center. Monitoring and control are indispensable parts of the smart systems and IoT. Especially in the big buildings and industry, infrastructure and production systems should be monitored continuously.

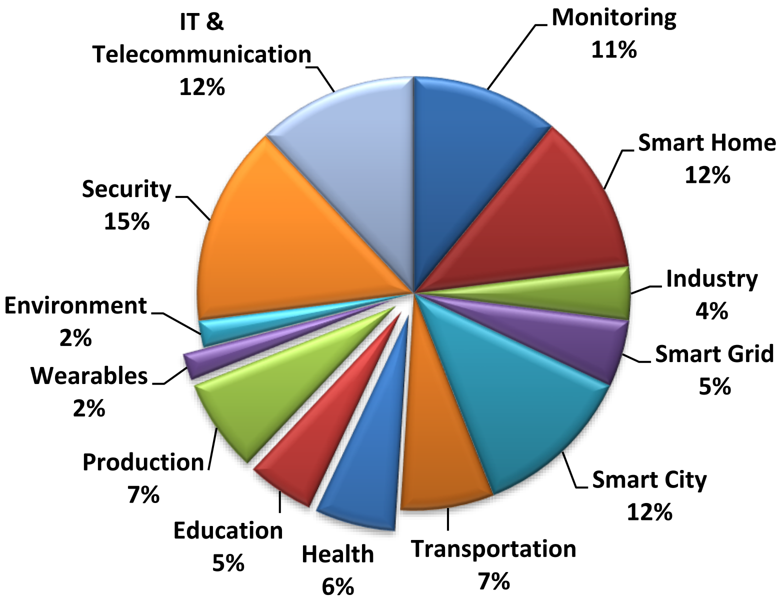


Figure 2.5. Percentages of IoT usage fields

As it is stated that in (Khanna and Tomar, 2016; Kelaidonis et al., 2016; Tai et al., 2015; Duarte et al., 2016), the monitoring technologies can be used in public transportation, water risk management systems, energy management systems, data storage, cloud systems, and forth (Huang et al., 2017).

As can be seen in Figure 2.5, smart systems such as smart home, smart grid, smart city, and security area have been pioneered to other fields. Investigated studies show that in the medical and health fields, the use of the IoT has been improved very rapidly. Studies conducted on the medical field have led to the formation of smart hospitals.

According to the related work emphasized above about IoT and its applications applied in different fields and locations, the survey chart of their usage fields is shown above. The chart data is derived from Table 2.2.

Table 2.2. Application fields with related works

Application Fields	**Related Work**	
Smart Home	(Al-Faris et al., 2017),	(Chew et al., 2017),
	(D'Oca et al., 2018),	(Darianian and Michael, 2008),
	(Garcia et al., 2017),	(Khan et al., 2016),
	(Kodali et al., 2016),	(Kuzlu et al., 2015)
	(Lu, 2015),	(Reynolds et al., 2017),
	(Salman et al., 2016),	
	(Stojkoska and Trivodaliev, 2017),	
	(Wenbo et al., 2015),	
Industry	(Aste et al., 2017),	(Jo et al., 2017),
	(Lu, 2017),	(Lu, 2015),
	(Ning et al., 2015),	
Smart Grid	(Chiu et al., 2017),	(Filho et al., 2016),
	(Good et al., 2017),	(Lee et al., 2017),
	(Mohanty et al., 2016),	
	(Shah and Yaqoob, 2016),	
Smart City	(Addanki and Venkataraman, 2017)	
	(Atif et al., 2016),	(Bibri and Krogstie, 2017),
	(Bruneo et al., 2016),	(Chew et al., 2017),
	(Dhungana et al., 2016),	
	(Gyrard and Serrano,2015),	
	(Kyriazis and Varvarigou, 2013),	
	(Mohanty et al., 2016),	(Nandury and Begum, 2016),
	(Pham et al., 2015),	(Reynolds et al., 2017),
	(Sun et al., 2016),	(Zabasta et al., 2016),
	(Zanella et al., 2014),	(Ziegler et al., 2016),

Table 2.2. Continue

Application Fields	**Related Work**	
Transportation	(Abueh and Liu, 2016)	(Atif et al.,2016),
	(Duarte et al., 2016),	
	(Kaiwartya et al., 2016),	
	(Mohanty et al., 2016),	
	(Nandury and Begum, 2016),	
	(Shukla et al., 2016),	(Zanella et al., 2014),
	(Zhong et al., 2017),	
Health	(Bal and Abrishambaf, 2017),	
	(Duretti et al., 2015),	(Kubler et al., 2017),
	(Martins et al., 2014),	(Mohanty et al., 2016),
	(Pramanik et al., 2017),	(Venkatesh et al., 2017),
Education	(Bagheri and Movahed, 2016),	
	(Corno and Rusis, 2017),	
	(Delfanti et al., 2016),	(Mäenpää et al., 2017),
	(Merino et al., 2016),	(Raikar et al., 2016)
Production	(Jo et al., 2017),	
	(O'Grady and O'Hare, 2017),	
	(Salman et al., 2016),	(Shah and Yaqoob, 2016),
	(Song et al., 2014)	(Wang et al., 2016),
	(Wolfert et al., 2017),	(Zhao et al., 2016),
Wearables	(Huang et al., 2017),	(Swan, 2012),
Environment	(Ma et al., 2013),	
	(Spalazzi et al, 2014),	
	(Zhu et al., 2015),	

Table 2.2. Continue

Application Fields	**Related Work**	
Security	(Abueh and Liu, 2016),	(Alaba et al.,2017),
	(Elbouanani et al., 2015),	
	(Fischer and Gessner, 2012),	
	(Gandotra and Jha, 2017),	
	(Gandotra et al., 2017),	(Garcia et al., 2017),
	(Hellaoui et al., 2017),	(Horton et al, 2017),
	(Kasinathan et al., 2013),	
	(Kodali et al., 2016),	(Miorandi et al., 2012),
	(Nguyen et al, 2015),	(Oriwoh et al., 2013),
	(Pishva, 2016),	(Rayes et al., 2012),
	(Saied et al., 2013),	(Sain et al., 2017),
IT & Telecommunication	(Al-Fuqaha et al.,2015),	(Alhamedi et al., 2014),
	(Al-Qaseemi et al., 2016),	
	(Gandotra and Jha, 2017),	
	(Gazis et al., 2015),	(Guinard et al., 2010),
	(Khan, 2017),	(Kelaidonis et al., 2016),
	(Lamaazzi et al., 2014),	(Oppermann et al., 2015),
	(Perera et al., 2014)	(Saied et al., 2013),
	(Tai et al., 2015),	(Wu et al., 2016),
	(Xu et al., 2012),	
Monitoring	(Duarte et al., 2016),	(Huang et al., 2017),
	(Khanna and Tomar, 2016),	
	(Kelaidonis et al., 2016),	(Luo and Ren, 2016),
	(Ma et al., 2013),	(Molina-Solana et al., 2017),
	(Spalazzi et al, 2014),	(Smith, 2016),
	(Song et al., 2014),	(Suciu et al., 2017)
	(Tai et al., 2015),	(Wang et al., 2016),

It can be categorized that the applied IoT projects, which were mentioned in detail in this section, in Figure 2.6.as shown in below. It is clearly seen that the utilization of IoT is ranging from the individual usage to the corporational usage. This result shows that this technology has already a substantial position among the other technologies, and its importance will strengthen day by day.

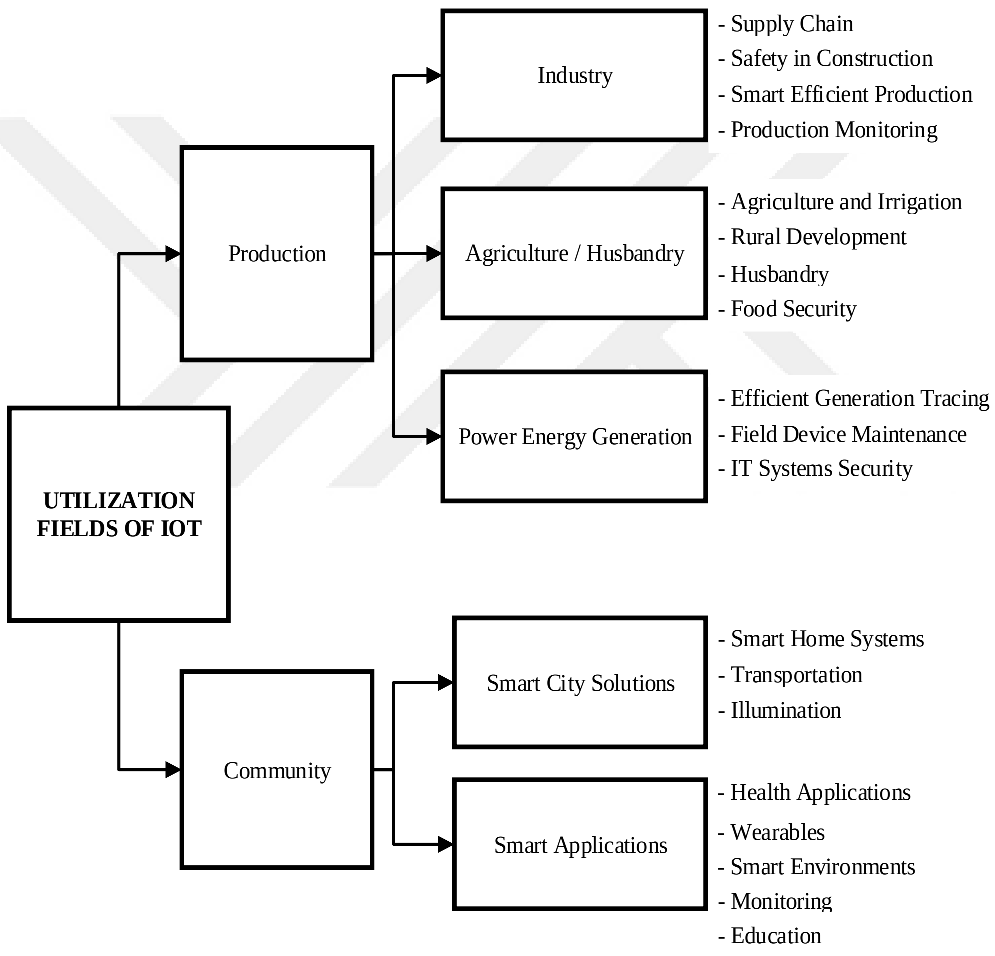


Figure 2.6. Utilization fields of IoT

2.4. Summary

Before the literature review section, introduction section is given. In introduction section, general definitions of the realized project are given.

In this section, a comprehensive review on smart systems, embedded systems and Arduino, and IoT and communication protocols are presented. This section summarizes papers and practical studies collected under three headings.

In the first section of this section, general information about smart systems is given especially smart building, smart home, and smart plug. Primarily, smart systems and the components of them are presented. While the definitions and related literatures are investigated, some points have been drawn the attention as follow.

- The European Council have the European Union’s 20–20–20 strategy.This strategy means 20% reduction of the total energy consumption, 20% contribution of renewable energy sources to total energy production, and 20% reduction of greenhouse gases until 2020 (Gokce and Gokce, 2014).
- In the investigated studies, buildings consume 40% of annual energy cost in U.S., and 30% of energy consumption is wasted (Jiechao, 2014; Costa et al., 2013). The energy consumption of buildings during the whole life cycle is responsible for 40% of total European Union (EU) energy consumption too. In addition, greenhouse gas emissions since buildings account for 36% of EU’s total CO_2 emissions. Future projections indicate that in 2030 buildings will be responsible for 35.6% of primary energy use in the world, and continue to maintain its importance (Gokce and Gokce, 2014).
- Restaurants 31%, hotels 25%, offices 39%, shopping centers 49%, hospitals 18%, schools/universities 34% and residential 27% have energy saving potential percentages (Gokce and Gokce, 2014).

- Understanding where and how you use energy can yield up to a 10 percent savings, without significant capital investment.
- Realized investigations show potential energy savings between 10% and 30% by adjusting the different sensors and control settings (Heller and Orthmann, 2014).
- Control methods can be summarized as manual, automatic, and remote control.
- In a smart system, controlling and monitoring are indispensable.
- All of the investigated studies related to smart systems are summarized in detail.

In the second section, embedded system cards are presented comparatively. Both advantages and drawbacks of the embedded cards have been expressed. Arduino embedded card is selected from the all other embedded cards. The most important conclusions of this second section are as follows:

- The most widely-used and well-known embedded systems in the literature are Raspberry Pi, Panda Board, Beagle Board, Parallax Basic Stamp, Arm, Basic Micro, and Arduino.
- When the conducted studies are investigated, it is seen that the most used cards are Arduino and Raspberry Pi respectively in academic studies.
- In Turkey markets, almost all Arduino cards can be obtained easily. When Raspberry Pi compares with Arduino, it is second order.
- There are a lot of sample applications which are realized by using Arduino in literature. Many studies are summarized in literature review section. Because Arduino has many advantages, it has been choosen in this thesis.
- Arduino boards are classified to four main sections named “Entry Level”, “Enhanced Features”, “Internet of Things” and “Wearable” boards. Entry

Level boards are for beginner users. According to this classification, all Arduino boards are presented in a table briefly.

- Arduino boards can communicate with the help of serial communication protocols named UART, I^2C and SPI.
- Studies realized by using arduino are summarized eventually.

Finally, in the third part of the literature review, studies about IoT and the definition of the IoT are presented in detail. The main points of IoT can be outlined as follows.

- Network topologies can be classified in four forms. These forms are named as pair, star, mesh, and cluster tree.
- In the IoT section, it is reviewed the communication protocols and standards which are used in IoT applications all over the World comprehensively.
- In this section, Wi-Fi, bluetooth, and ZigBee wireless communication protocols are compared to each other.
- After the investigation of the realized studies, ZigBee which has 802.15.4 standard of IEEE is preferred. In this study, both positive and negative sides of ZigBee are given.
- The emerging idea of IoT concept has been already its own path throughout our modern life, by upgrading the quality of life with smart devices and technologies. IoT is a natural conclusion of smart devices.
- As a difference from the other papers and related works, the purpose of this paper is to categorize the whole concept in one main detailed communication protocols table.
- Besides the detailed table, it is aimed it to be understood clearly what IoT is, where it can be used efficiently, and what are the advantages. Thus, it is

analyzed different types of applied projects in diverse locations all over the globe, and the aim of showing how large usage spectrum it has.

- The usage ratio of each application field is finally presented by taking the reference papers as criteria. The detailed charts and tables were presented to illustrate the importance of communication protocols.

3. DESIGN AND IMPLEMENTATION OF SBMS

SBMS consists of three different parts named EMS, SCS, and FDCS. These three parts have been explained in the next sections in detail. The combining of these parts and software solutions brings about SBMS. Thanks to SBMS, clients can access to their devices connected to the SBMS and can manage them, remotely by using their mobile or other devices such as PC and Laptop computer.

Before the introducing of SBMS and other sections, some general information should be known. As previously mentioned in the scope of the thesis, this study mainly consists of three main parts. These parts can be named as embedded system part, administrative part, and client part.

While the thesis projects are realized, process sequences are important. Previously, after the hardware features determine, materials such as sensors, relays, actuators and other appliances should be selected. In this step, embedded cards in market have been investigated and compared with each other. As a result of the investigations, Arduino microcontroller has been preferred. Subsequently, electronic equipments, shields, and other cards compatible to Arduino has also selected. In addition, communication protocols have been investigated and ZigBee wireless communication protocols has been preferred because of its positive sides such as cost, reliability, low power consumption, and forth.

In the thesis project, after the selection and mounting of the physical hardware parts, Arduino IDE software has been used for programming of embedded cards. In the beginning of the thesis, different codes has been written for every card. Afterwards, according to duty of cards and the location in network topology, all embedded cards has been classified as either coordinator or router/end node devices. Thanks to this classification, all cards are grouped under the two class. As a result, two different codes have been written for all Arduino boards.

The entire embedded cards can be communicated each other by using ZigBee communication protocol. For the ZigBee communication, XBee modules should be connected to Arduino boards. This connection can be realized either copper cable or shields compatible to Arduino card type. Copper cable can be used for connection between XBee module and the embedded card directly or can be used with the helping of breadboard. Because shield connection is more durable than the others, connection via shield has been chosen. Cards required to perform Zigbee connection are shown in Figure 3.1. These cards are shown in Figure as XBee module, XBee shield, and Arduino Mega ADK board separately.

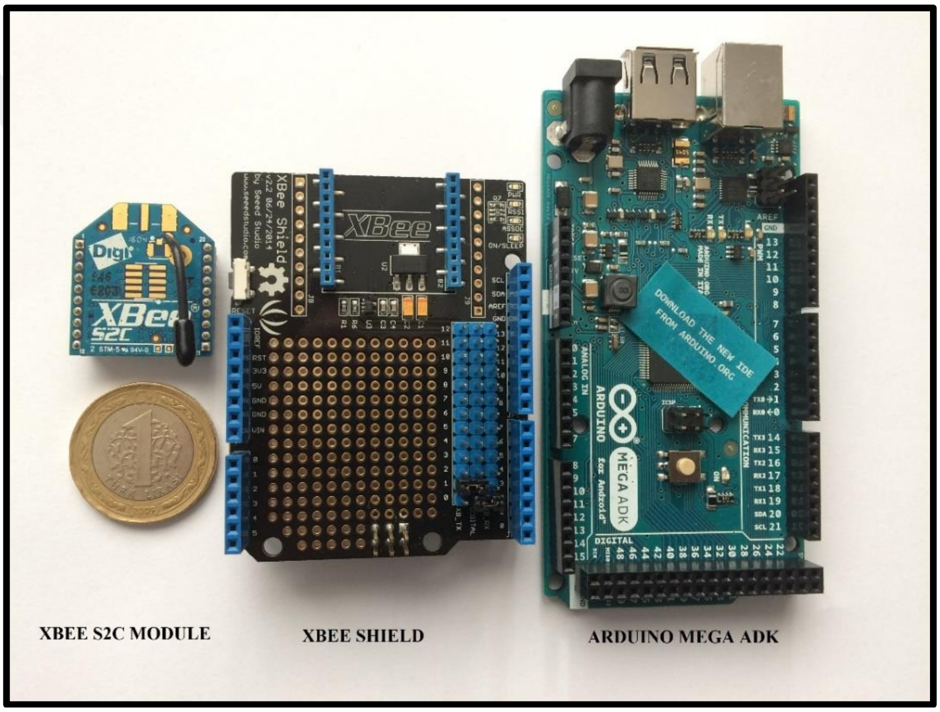


Figure 3.1. Separate display of electronic cards for ZigBee connection

While the combining of these cards, it is seen that XBee shield has been designed for Arduino UNO. During the Xbee shield is inserted into Arduino Mega card, it is noticed that TX/RX pins of shield overlap with the Arduino mega TX0/RX0 used as USB port for computer communication. In order to prevent data collision, XBee shield ports have been transferred to another UART port of Arduino mega with two copper wires as diagonally as shown in Figure 3.2. In this figure, all separate cards have been combined.

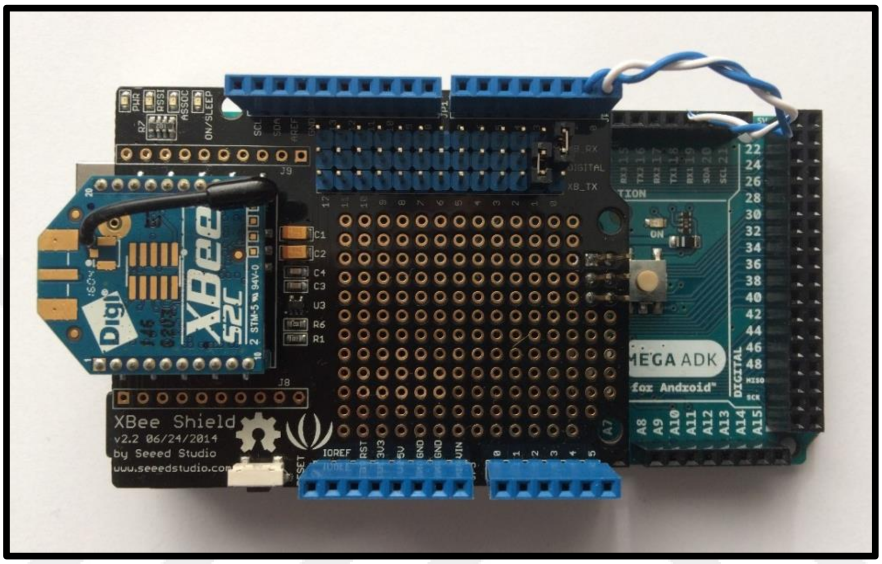


Figure 3.2. The connection of ZigBee into Arduino Mega with XBee shield

Before the XBee module is inserted into the XBee shield, it should be programmed. In order to programme XBee module, XBee Configuration&Test Utiliy (X-CTU) software which is developed by DIGI International Company and XBee USB Adapter Board (X-UAB) which has FTDI chip (Future Technology Devices International) have been needed. XBee module should be plugged into X-UAB by paying attention to the module direction. After the Xbee module is plugged to the X-UAB, X-UAB can connect to a computer via mini USB cable. Thanks to Windows 7 or later operating system, FTDI driver has been recognized automatically. Otherwise, FTDI driver can be downloaded from the Internet and can be loaded to computer easily. Afterwards, XBee module can be defined as either coordinator or router/end node device with the helping of X-CTU software. X-UAB. X-UAB is shown in Figure 3.3. As can be seen in the figure, mini USB cable is used for connection of X-UAB to the computer.

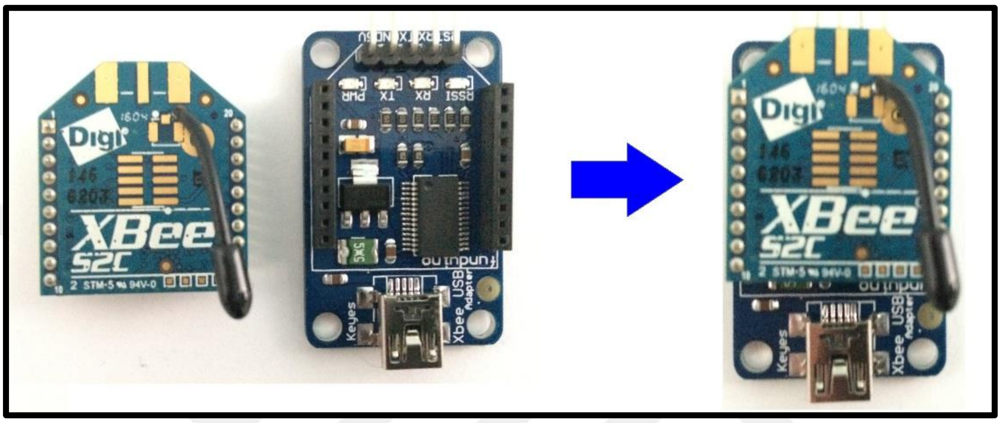


Figure 3.3. XBee USB adapter board

After connection of X-UAB, XBee module can be programmed by using X-CTU. All parameters of XBee can be adjusted. During the adjustment, XBee module should be defined as either coordinator or router. Router and end node device are considered as same in a view of usage type. If XBee module is to be assigned as coordinator, “CE Coordinator” parameter must be done enable. If it is to be assigned as router, “JV Channel Verification” parameter must be done enable similarly. All XBee modules within the same network must have the same PAN ID, regardless of whether they are coordinators or routers. Finally, “Scan Channel” and “Destination Address Low” parameters are changed and adjustment is completed. Scan Channel value is changed from 7FFF to FF and Destination Address Low parameter is changed from 0 to FFFE. X-CTU software has been shown in Figure 3.4.

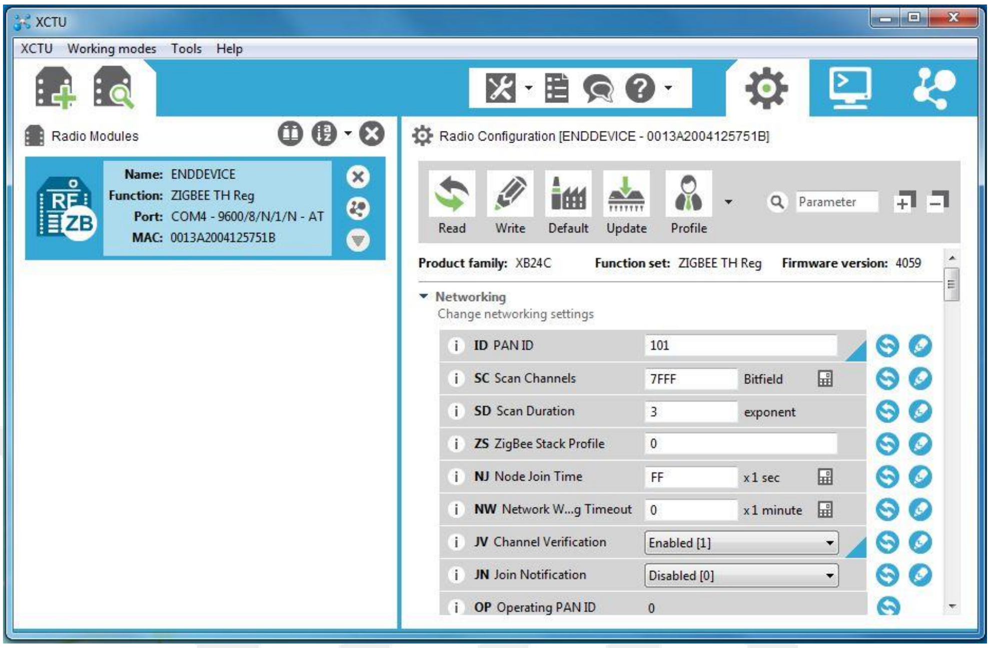


Figure 3.4. XBee Configuration & Test Utiliy software

3.1. A Novel Algorithm for Arduino Boards

Embedded codes have been written independent from each other individually on all investigated projects so far. Individual writing of codes has both positive and negative sides. The most important positive feature is the ability to write code easily. Since there is no dependent code writing capability, code writing is easy. However, this situation occurs obligation to write different codes for each microcontroller card. In order to prevent this obligation, a single code has been written for coordinator node card and a different single code has been written for all router and end node cards too. All arduino cards according to where they are used have either coordinator or router/end devices features. Because of this, whatever the task of the used card is, it will abide by one of these two standard codes.

3.1.1. The Integration of Coordinator Node Card

The duty of coordinator node card is to transmit data from all other cards to the main computer or from the main computer to all other cards each other. As shown in Figure 3.5 and Appendix A, after the connection of USB and ZigBee ports as Serial connection, data which comes from USB sends to ZigBee and data which comes from ZigBee sends to USB automatically.

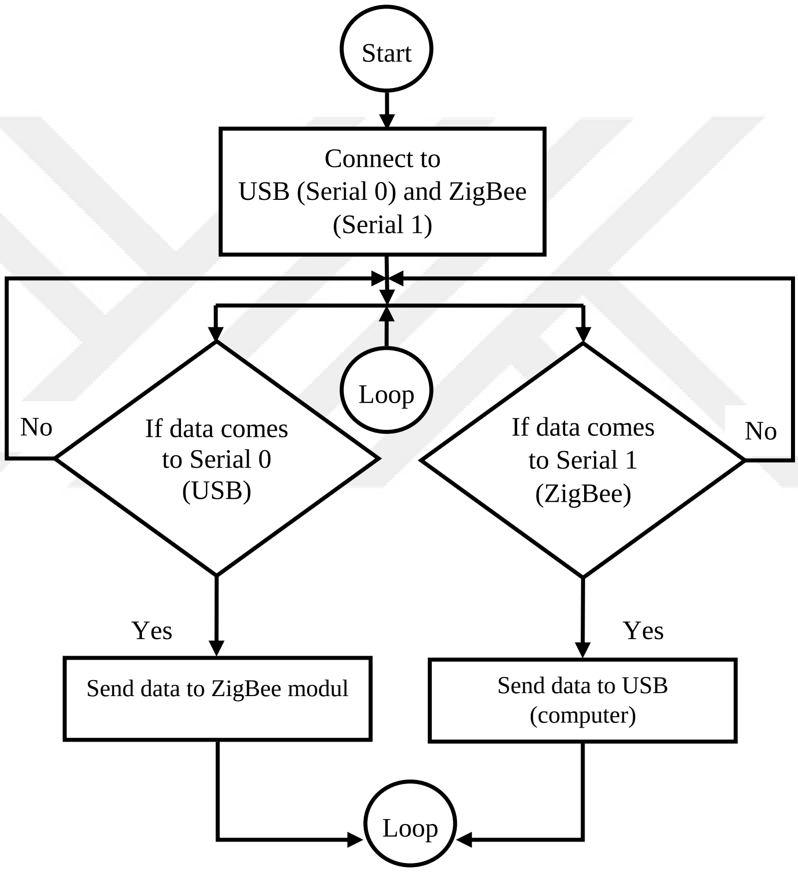


Figure 3.5. Flowchart of coordinator nodes embedded codes

3.1.2. The Integration of Router and End Node Cards

Codes which are written for router and end nodes show differences from one node to another node as depending on used sensor types. In order to prevent writing separate code for each card, standard code has been developed for router and end node cards. Codes are written and format of the used commands have shown in Appendix A and Figure 3.6 respectively. How codes work has explained in the below rows.

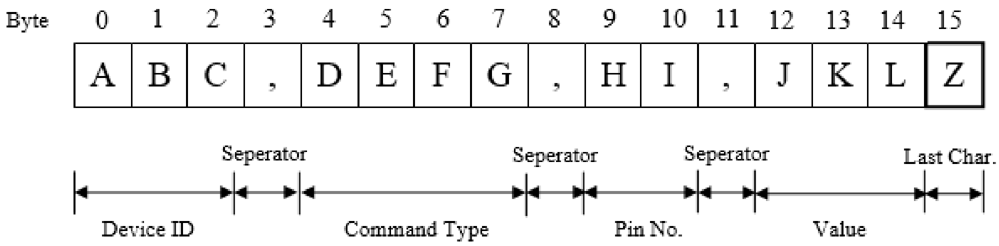


Figure 3.6. The format of used commands in router and end node cards

In order to take place a network with the coordinator, router and end node cards, some features should be considered. Primarily, all cards have to possess same PAN (Personel Area Network) number. Then, ZigBee modules have to define as either coordinator or router. Because router cards have the same features with end node cards, all end nodes define as router. Finally, serial communication ports of embedded cards which connects to ZigBee module have to reassign new available ports. After all adjustments, code writing can be started.

Primarily, first three characters from left of command defines to device identification number. Then, comma separator is used in order to understand the code more clearly. Next four characters are for defining of command type. Command type can be taken four different values named as Digital Read (DGRD), Digital Write (DGWR), Analog Read (ANRD), and Analog Write (ANWR). After the comma separator, if which pin is used, that pin’s number defined. After the defining of the pin number, comma separate is used again to prevent mess. Lastly, according to used command type, analog or digital value are entered and added Z letter to understand end of the command line. Thanks to this algorithm, general codes will be standardized. The flowchart of this software is shown in Figure 3.7.

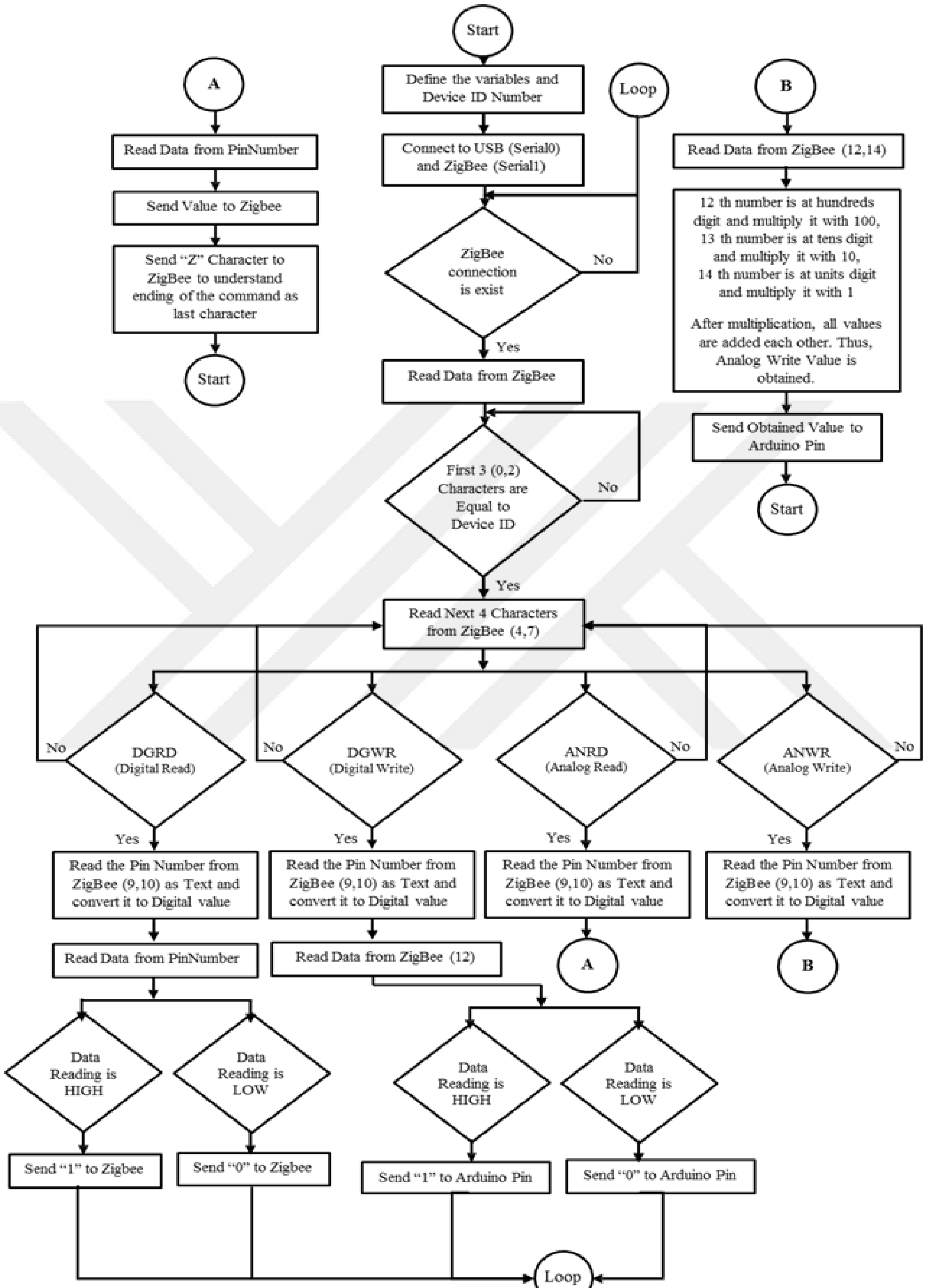


Figure 3.7. Flowchart of router/end nodes embedded codes

4. DESIGN AND IMPLEMENTATION OF EMS

4.1. Design and Implementation of Smart Plug

In this section, a low cost smart plug is aimed to design in order to measure the energy consumption and to realize energy saving. Current and voltage values, and power factor will be measured by using embedded card, namely Arduino. When a conventional device is connected to the proposed smart plug, the device turns into smart one which is controllable remotely. As a consequence, enormous energy saving is expected by using the proposed smart plug globally.

In this realized study, a smart plug was firstly designed as a prototype for the real-time measurement of the amount of appliances' electrical energy consumption. In order to determine the amount of electrical energy consumption of each appliance, it will be adequate to connect the electric circuit of the appliance to the designed smart plug. By the sensors of the smart plug, parameters that determine or affect the electrical energy consumption such as current, voltage, cos φ, the frequency can be measured. The amount of appliance's energy consumption will be measured by the smart plug after the calculations. It will be conducted to the program that is executed on the server. Via software that will be developed on the server, data coming from the smart plug will be monitored at server screen with respect to simultaneously. All data which read simultaneously should be saved according to sampling time. By the analysis of these data, periods that the appliance is used frequently, hours that the appliance consumed the maximum energy, and values that the appliance's maximum energy consumption amount should be determined and aimed to develop algorithms for energy saving.

In this study, physical installation should be realized firstly. After the hardware installation microcontroller must be programmed. Arduino IDE software has been used to write codes for microcontroller with ATMEL integrated circuit. When the microcontroller software is completed, the server should be installed to connect between microcontroller and software solutions. The server has Windows

Server 2012 R2 operating system. Server software has been written by using Delphi compiler. This software helps to the administrator to adjust all parameters. Server application is like a bridge between plug and users. Finally, desktop and android based application is written for the users by using Delphi compiler and web based application is converted from the desktop application by using Thinfinity VirtualUI software of Cybele Software. In order to occur a connection between microcontroller and server, ZigBee modules have been used as shown in Figure 4.1.

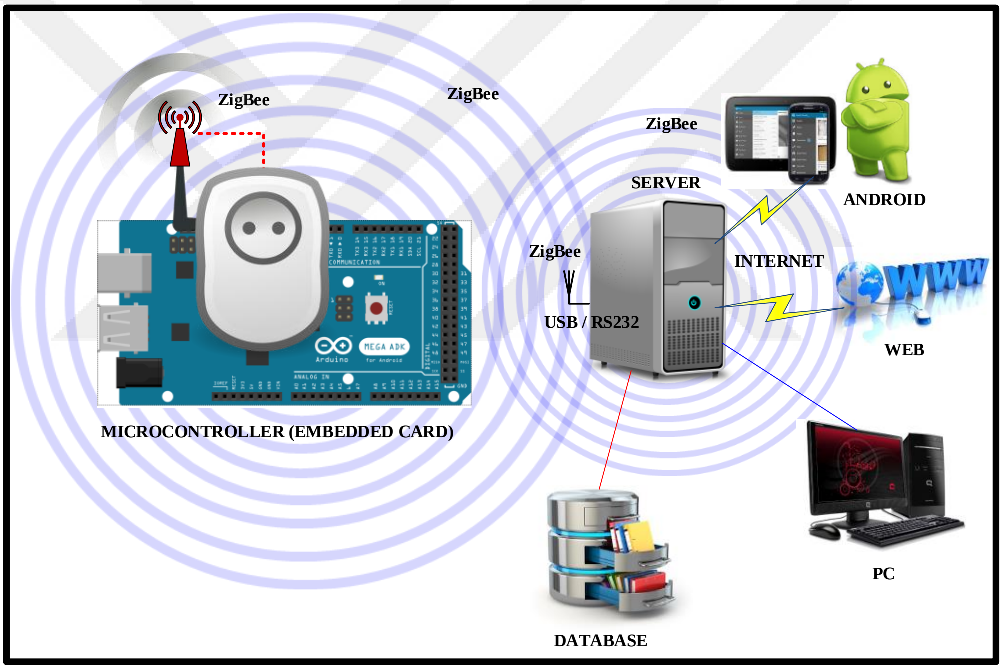


Figure 4.1. Schematical view of Smart Plug design

While a smart plug designs, some instruments are needed such as a current sensor, a voltage sensor, a microcontroller, a relay, Zigbee modules and etc. Owing to current and voltage sensors, voltage and current values can be measured easily. In order to learn cos φ, zero points of voltage and current should be determined. Moreover, the difference between voltage and current zero points should be known the phase difference as milliseconds. This milliseconds value can be converted to angle values. This value is enough to calculate the cos φ. After cos φ value finds, active power and reactive power values can be calculated easily. Operational Amplifier circuits (Opamp) are used for finding cos φ value. Symmetrical voltages are used to arrange output voltages of operational amplifiers. Symmetrical voltages prevents output voltage of opamp from passing 5 volts. Because arduino inputs can withstand up to 5 volts, the usage of symmetrical voltage is vital important to work the system correctly. If users want to control the smart plug, ON/OFF control can be realized remotely through the desktop, web or android based software solutions. Designed circuits and measured values in the working principle of smart plug section has been expressed in detail.

4.1.1. Simulation of Zero Point Detection and Cos φ Determination

When the previous studies are investigated, it is shown that either cos φ is accepted as 1 or cos φ meter in central power distribution panel is used for learning of power factor value instead of indivual measuring. The central measuring of cos φ, instead of the individual measurement, has not been complied with the designed smart plug logic. In order to measure right values, the value of the power factor that each device brings to the circuit should be measured separately.

In order to accurately determine power factor value, zero points of voltage and current should be determined. After the zero points of current and voltage values are found, difference between two points should be calculated. Before the cos φ measurement circuit is realized, simulation studies should be realized to determine whether the measurement is accurate or not. PSCAD/ EMTDC software has been preffered for simulation. Simulation studies have been realized for RL, RC, and R circuits. RL simulation circuit realized by PSCAD/EMTDC is shown in Figure 4.2. In addition, the other two circuits (RC and R) and their graphical results are also shown respectively.

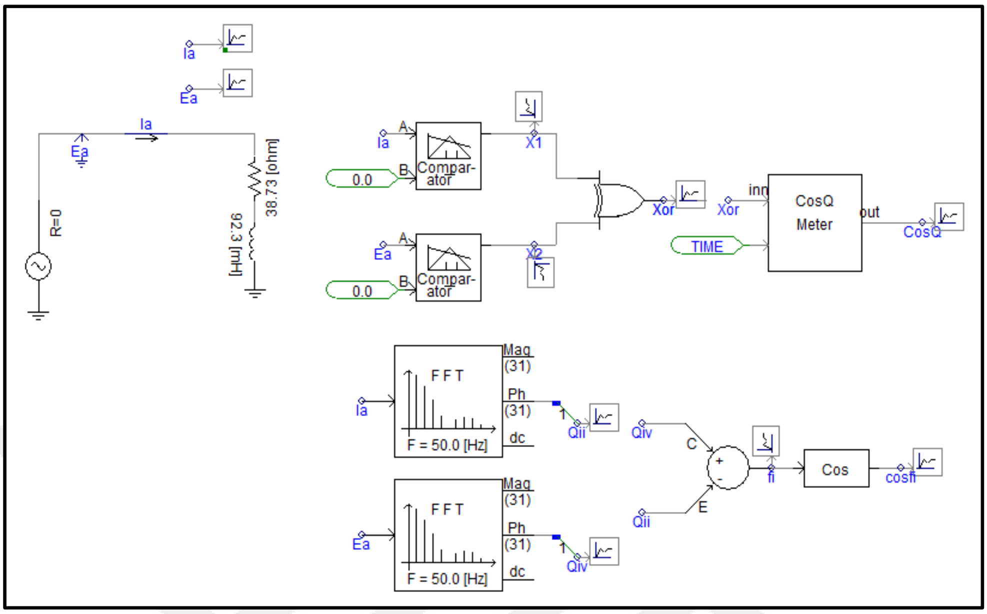


Figure 4.2. PSCAD simulation circuit of cos φ for RL load

As seen from Figure 4.2, the current and voltage values of the system are measured. After that, the zero cross points of the current and voltage are determined by utilising the comparators. Then, by using the XOR gate, time difference between zero crossings is extracted. This process is repeated for 5 cycles, which corresponding to 1 second, and an average time value is obtained. Lastly, this average time value is converted to degree and radian, respectively.

As a result of RL PSCAD/EMTDC simulation circuit, the graphics shown in Figure 4.3 and Figure 4.4 are obtained. In the first graphic, voltage, current and the output of the XOR gate are shown. In the second graphics, the results of comparators and the output of XOR gate are also shown respectively.

In the circuit in Figure 4.2, R is left unchanged and the L bobbin is replaced by 109.76 uF capacitor C. As a result of this changing, the RC circuit is obtained. Similarly, in order to obtain R circuit, the cancelling of L bobbin in the circuit will be enough. In the all graphics, the relationship between voltage and current has been shown clearly.

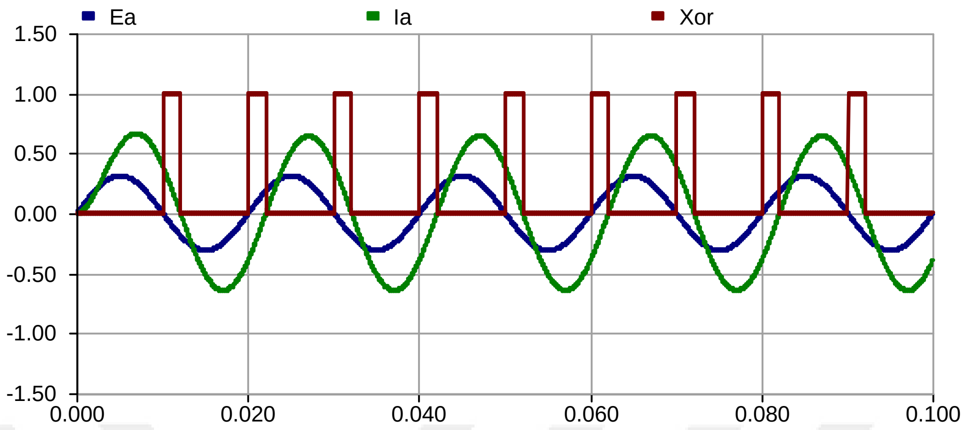


Figure 4.3. The result of the RL-PSCAD simulation circuit

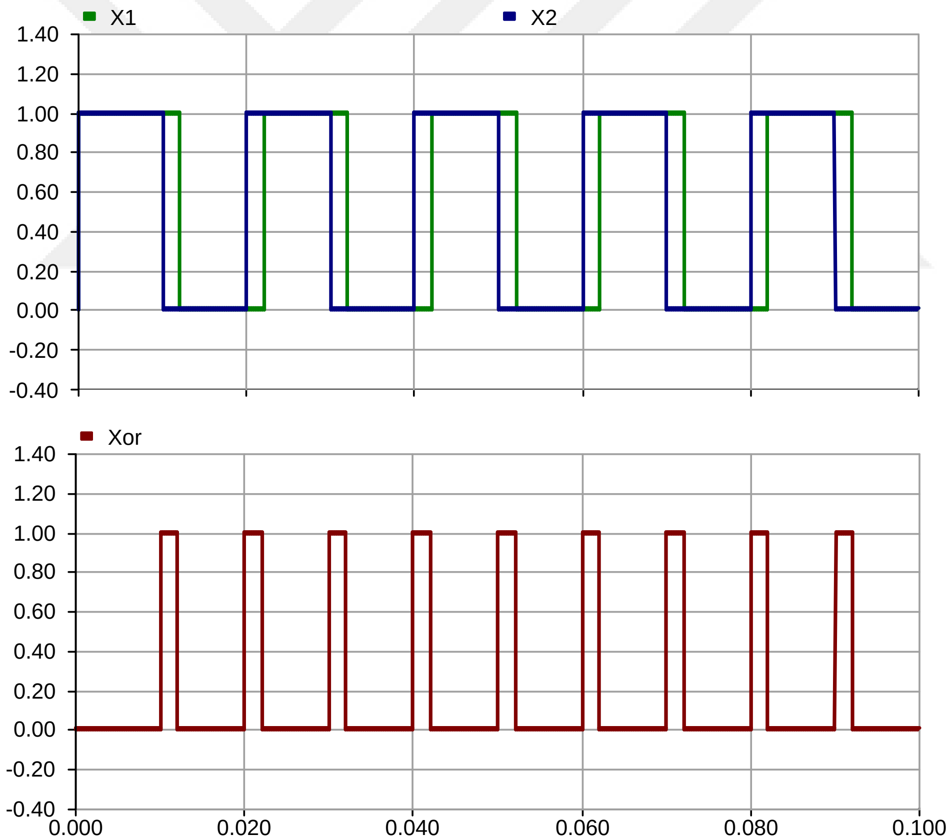


Figure 4.4. The results of comparators and XOR gate in RL-PSCAD circuit

The results of realized RC circuit simulation are shown in Figure 4.5 and Figure 4.6 seriatim.

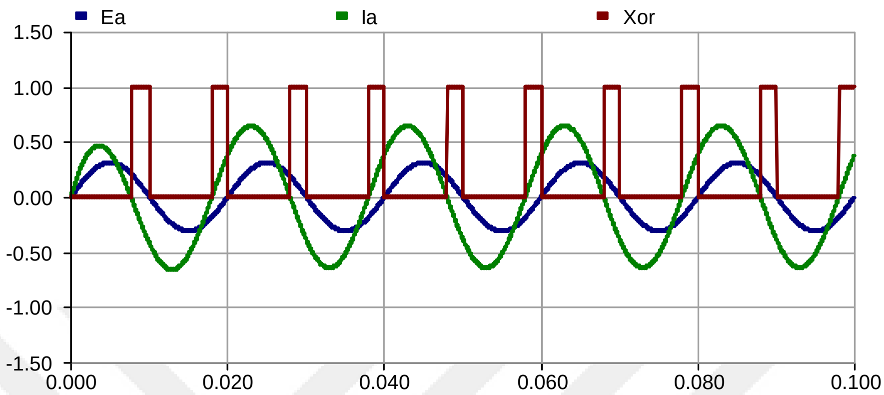


Figure 4.5. The result of the RC-PSCAD simulation circuit

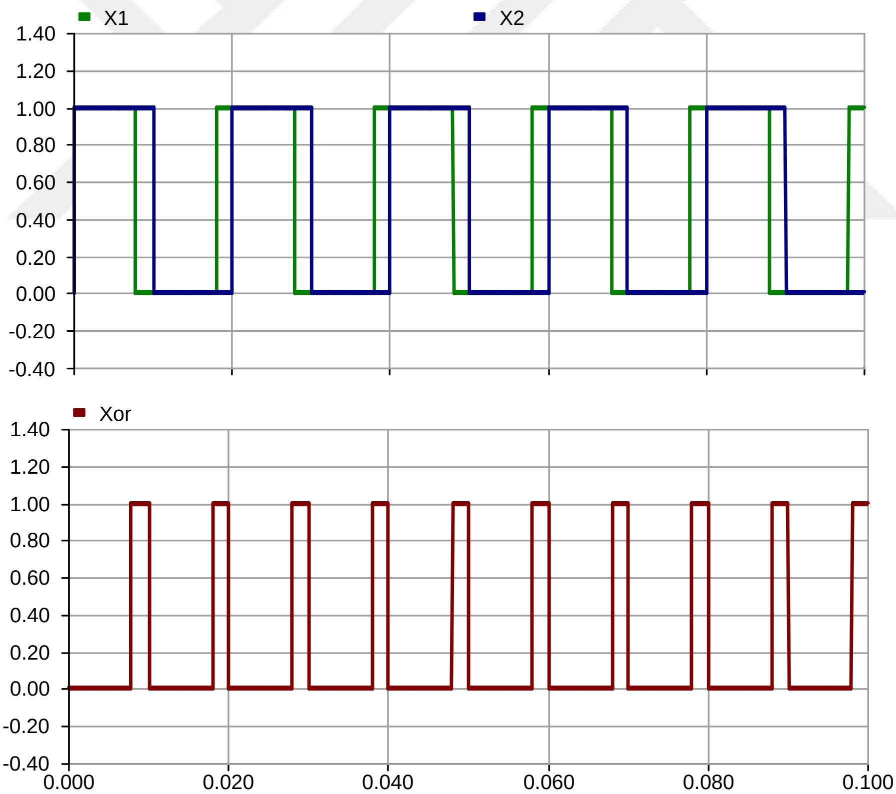


Figure 4.6. The results of comparators and XOR gate in RC-PSCAD circuit

The results of realized R circuit simulation are shown in Figure 4.7, Figure 4.8, and Figure 4.9 respectively.

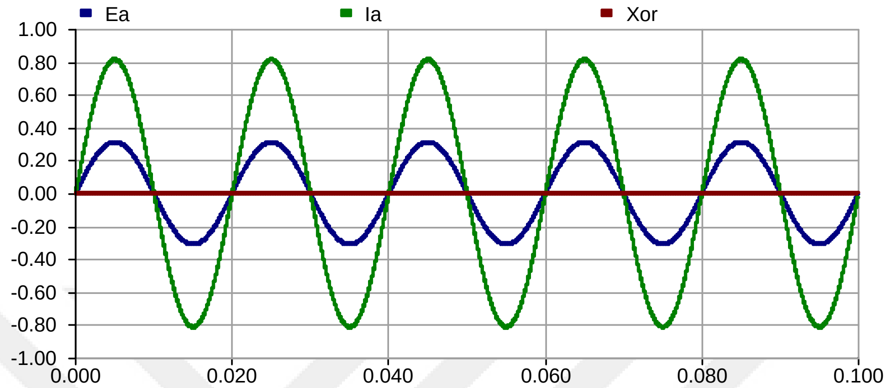


Figure 4.7. The result of the R-PSCAD simulation circuit

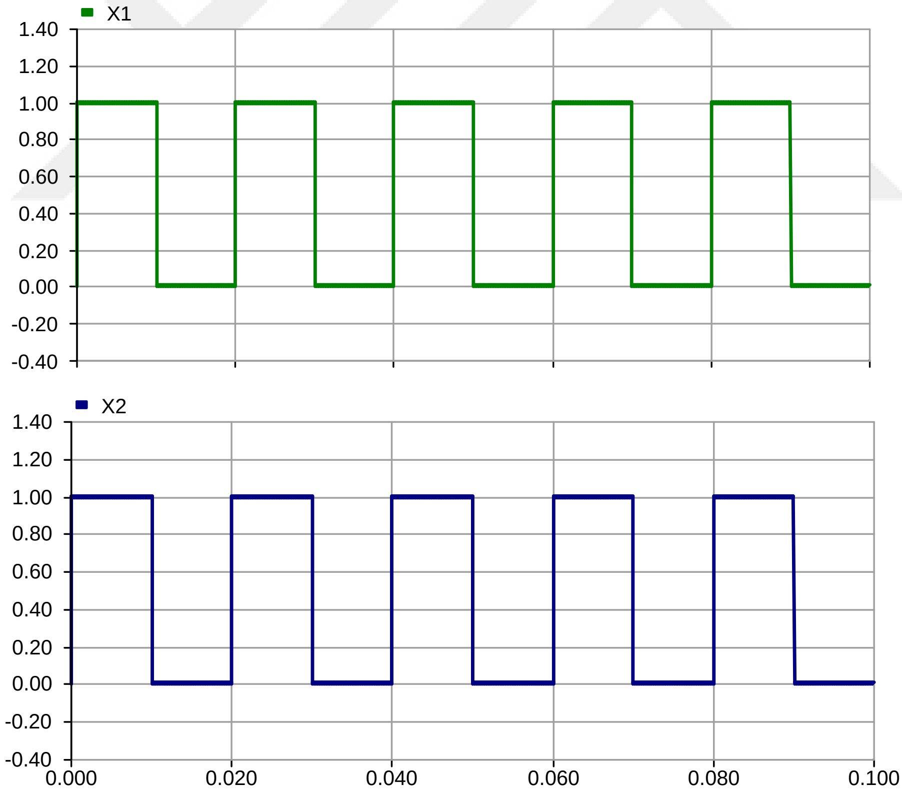


Figure 4.8. The results of comparators in R-PSCAD circuit

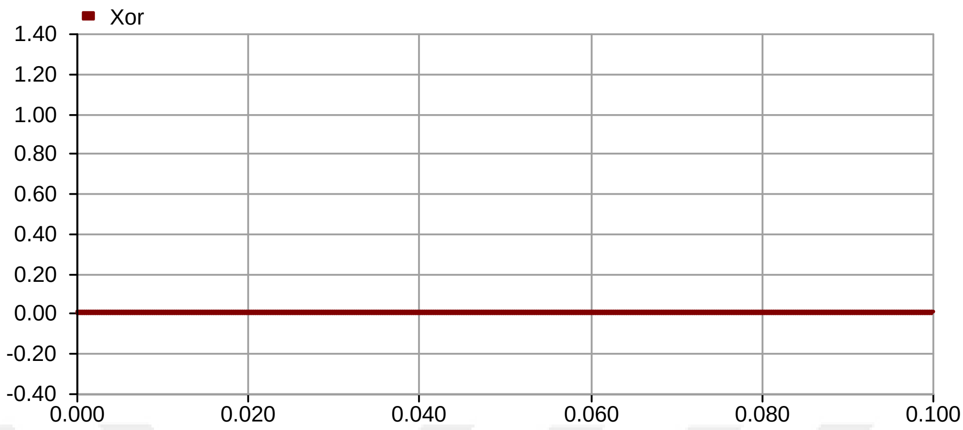


Figure 4.9. The result of XOR gate in R circuit

Since there is no phase difference between current and voltage in resistive circuits, the voltage and current graphs overlap each other. For this reason, the current and voltage waveforms are given separately.

After the PSCAD/EMTDC simulation studies, it was decided to design a smart plug which can be measured voltage, current, frequency, and cos φ values instantly. All the details which is related to the realized study are given below paragraphs.

4.1.2. The Working Principle of Smart Plug and Implemented Studies

The main objective of Smart Plug project is to develop a plug that can be controlled and monitored remotely. It is aimed to measure and record the consumed energy amount of single phase 220 V devices by developed smart plug. In addition, it is aimed to control the plug by switching ON/OFF remotely. It is aimed to realize the remote monitoring and control of the plug by Windows, Web and Android based applications. Critical set values of measured values are determined and in case of exceeding these values, the energy connection of the devices are going to be automatically turned off. As a result of analysing the recorded data, it is aimed the save energy by using energy more efficiently.

In this project, first of all, material selection is made in accordance to required properties for a smart plug. The implementation of material selection is done by following to perform accuracy tests of materials. It is targeted to measure voltage, current, frequency and cos φ values while the smart plug is designed. By these measured values, it is going to be possible to calculate the power consumption of the device which is plugged into the smart plug. Furthermore, relay with the microcontroller is used to switching the power supply of plugged in device. The microcontroller plays a key role in the implementation of both control and monitoring functions.

Arduino microcontroller with the ATMEL microprocessor is chosen because of the ease of use, cost, and the amount of similar applications, availability from the market, and the wide range of sensors and other equipment that can be used with it. Essentially, an Ardiuno microcontroller comprises of Atmel microprocessor, USB serial programmer and power regulator units. Technical facilities for Arduino are given in Appendix A. The features of the Arduino Mega ADK include the Atmel 2650 processor, 54 digital I / O pins that can be used as 16-pulse PWM (Pulse Width Modulation) outputs, and 16 input pins that each of them are 10-bit analogue. It has a 256 KB flash memory totally. There are 4 UART communication pins that one of them is for programming.

The specificities of the microcontrollers are rather sufficient for a smart plug project. There is need for one digital input pin to turn on/off the smart plug. Moreover, there is also need for two analogues and two digital input pins to measure voltage, current, frequency and cos φ values of energized plug.

Different types of sensors and devices can be supported at the same time with microcontrollers that the design of it brings multitenancy. Hence, a temperature and humidity sensor is assembled to smart plug in order to measure the temperature and humidity of the environment.

Following the design of smart plug is completed, it is tested with a calibrated HIOKI brand device which can make accurate measurements, in order to determine the accuracy of the measured values. The results of test measurements indicate that measurements can be made with maximum of % 2 accuracy.

It is seen in the literature that such embedded systems or microcontroller applications are specific according to project. In other words, the code that is used to control microcontroller is specific to application and it is difficult or impossible to make changes on the project or make an attachments to it. In order to overcome this problem a new system which is able to read the sensors and transmit data in spite of the type and intended use of sensors that can be mounted on them is designed. The main advantage of this system is opportunity of the standardized software usage by downloading it to another microcontroller in case of breaking down of the microcontroller. In addition, any microcontroller used elsewhere in the system can be removed and replaced directly, without any hardware or software modifications, in case of breaking down or alteration.

Development, maintenance, repairment and training cost are minimized by this code standardization. Moreover, various applications that are required to be done can be realized in a simpler way.

Following the standardizing the codes, the electronic circuit is designed for microcontroller to switch the grid voltage and to read the voltage, current, frequency and cos φ. While the electronic circuit is being designed, the studies are performed by considering operating current and voltage of microcontrollers and other devices. The main objective of design is to make it practical, applicable, cost effective and coherent. Relay is preferred because of its ease applicability and cost advantage for switching operation.

In order to measure the grid voltage, step down transformer is used. Since the microcontroller only measures direct current, the output of the transformer is rectified and reduced with divider voltage resistors to keep it in the measurement limits of microcontroller.

The AC voltage from the step down transformer is rectified by low power single diode, filtered with fairly low power capacitance and connected to one of the analogue inputs of microcontroller in order to make measurement. In order to detect the minor variations in grid voltage, it is not rectified by full-wave and bridge diodes that can give better output and capacitor and filter circuits that can filter better. Half-wave rectification with a single diode reacts much faster than other rectification methods. The higher the quality of the rectifier and filter circuit, the more stable the voltage output will be, as the fluctuations from the network will compensate so well. This contradicts the aim of detecting the voltage sensitively, in other words detecting the small changes in grid voltage for his project. While calculating the voltage divider resistors, it has to be considered that analogue inputs of microcontrollers can stand to 5V DC voltage maximally. It is calculated by adding the safety margin that input voltage has to be 4V DC since maximum 5V DC voltage can be used. All calculations are made in according to 4V DC input value.

Since it is known that the main used voltage is 220 V AC, the voltage drop transformer ratio and the voltage divider resistors are selected as 100/1 in order to simplify the calculations. 2.2V DC voltage is provided to Arduino microcontroller as input voltage at the end of calculations. Microcontroller's input voltage drops to 2.1V DC following the grid voltage drops to 210V AC. Microcontroller's input voltage steps up 2.3V DC following the grid voltage steps up to 230V AC. If there is maximally 400V AC input, the input voltage of microcontroller can only be 4V maximally. Because of the input voltage can stands up to 5V, damage to the microcontroller is prevented consequently.

The rectifier which is at the output of step down transformer and voltage input at the output of filter elements are calculated as 6V DC when the grid voltage is 220V AC. The calculations are made in according to the resistance which feeds the analogue input of microcontroller is 2.20V voltage. The voltage of other resistor which is in voltage divider circuit is 3.80V. Total voltage is 2.20 + 3.80 = 6.00 V DC. According to this calculations, if the resistance which is connected to the analogue input of the microcontroller is 2.20 units, the other resistance value has to be 3.8 units. Resistance values have to be calculated correctly. It is aimed to consume minimum power due to minimum current is drawn from the rectifier and filter circuit. If the voltage divider resistance values are kept low, both the power consumption increases and the desired response speed cannot be obtained due to the excessive load on the rectifier and filter circuit. Conversely, when the voltage divider resistance values are too large, sufficient current pass is not provided for microcontroller to measure. Therefore, measurements result incorrectly.

The voltage from the microcontroller to analogue inputs is measured with 10 bit A / D converter (analogue digital converter) that is integrated into the microcontroller by converting it to digital. Since the microcontroller can accept input as a maximum of 5V DC, it corresponds to 10 bits i.e. 2^{10} = 1024. It means that measurements can be made with 5/1024 = 0.00488 V, approximately 5mV, sensitivity. Since our measurement cycle ratio is 100/1, it means that the grid voltage measurement can be made with 0.005V x 100 = 0.5 V sensitivity. This obtained sensitivity is sufficient for the needs of this project. Besides, the sensitivity level is reached to 0.1 V and 0.007 V respectively for more sensitive measurements by using 12 or 16 bit A / D converters externally and the average of all the measured values is found and this information is presented to the user as the mean value of the voltage.

ACS712 hall-effect current sensor is used for current measurement. The operation principle of hall-effect current sensor is finding a current that flows according to the amount of magnetic field generated by the current passing through a conductor. As the intensity of the current passing through the conductor increases, the effect of the magnetic field around the conductor also increases. The intensity of the current that is passing through the conductor can be calculated by measuring this generated magnetic field. The advantages of these sensors are that they can measure both AC and DC currents, they are sensitive and stable, and they provide good insulation even at high current ratings which are caused by the measurement of the magnetic field that is generated basically. Since it is calculated that the driven current in this project is 20A, it is decided to use the ACS712 current sensor of 30A by adding the safety margin. Since the alternating current measurement is performed, the current information from the sensor is continuously measured over a period of 1 second, and the current value is calculated by taking the average of all the measured values. Eventually, this average current value is sent to the user.

The voltage value which is obtained from the output of step down transformer for the measurement of frequency is applied directly to the inverting and non-inverting inputs of an Operational Amplifier (OPAMP), and an output voltage that is parallel to input voltage is obtained continuously except when the input voltage is 0. Because of corresponding of this obtained output voltage to each alternans of grid voltage that is given from input, frequency is double of input grid frequency. Researches on choosing proper OPAMP is completed and as a result, LM741 integrated circuit is preferred due to its wide operating voltage range, high input impedance and sensitivity, easy and cheap availability, rich documentation and application examples.

It is provided to generate an output signal for both positive and negative alternans which are supplied from input by supplying OPAMP +/- 5VDC with a symmetrical power supply. In addition, the values that are higher than 5 V are truncated and reduced to 5 V through this symmetrical feedback voltage. This produced output signal is given to one of the digital inputs of the microcontroller. The microcontroller has a function that can measure how long the signal applied to the digital inputs come both in negative and positive direction. It is reached to total number of positive and negative alternance by getting the duration of coming signal as microsecond and dividing it to 1 second time period. After that, this total number of alternans is divided by two to obtain the number of full alternans, that is, the network frequency. Since the measurement is made in microseconds, frequency measurement can be performed very sensitively. Firstly, a literature review is performed and a practically applicable circuit design was not encountered for power factor measurement. The phase angle between current and voltage must be known for the power factor measurement. It is decided to design a circuit that can follow both current and voltage based on this theoretical knowledge. Based on the idea that the OPAMP circuitry that is used in the frequency measurement circuit can generate signals for both voltage and current, one of these two OPAMP is connected to input voltage same as frequency measurement circuit and another one is connected to output of a current transformer which is used in order to detect the current drawn by the load

Output signals of both OPAMPs are 0 where the input voltage is 0. In other words, if the one of these two signals is 0, the counter begins to count until the other signal is being 0. If we find the duration time between first signal zero points and second signal zero points, we can find the duration between these two signals. That is phase difference. There are two different methods to do this calculation.

In the first method, the output signals of the OPAMPs are given to the digital inputs of the microcontroller. When one of these inputs is zero as a reference, a counter is operated and the other signal is expected to be zero and when the other signal is zero, the counter is stopped and the counter value is read. Thus, the phase difference can be measured as microseconds. It is necessary to work with a microcontroller which is fast and has a hardware interrupt support and sensitive counter for using of this method. This circuit is shown in Figure 4.10.

In Turkey, grid frequency value is 50 Hz and this means that one period is completed in 20 miliseconds. In the realized project, measurement period is one second. One second is a thousand milliseconds. If thousand milliseconds divides into twenty milliseconds, result obtains fifty. Because of measuring twice per period, a total of 100 measurements have been made. As a result of all measurement, the average value of total milliseconds are calculated. Obtained value is converted to radian value and radian value is also converted into degree value. In order to obtain power factor, the cosinus of obtained degree value should be calculated.

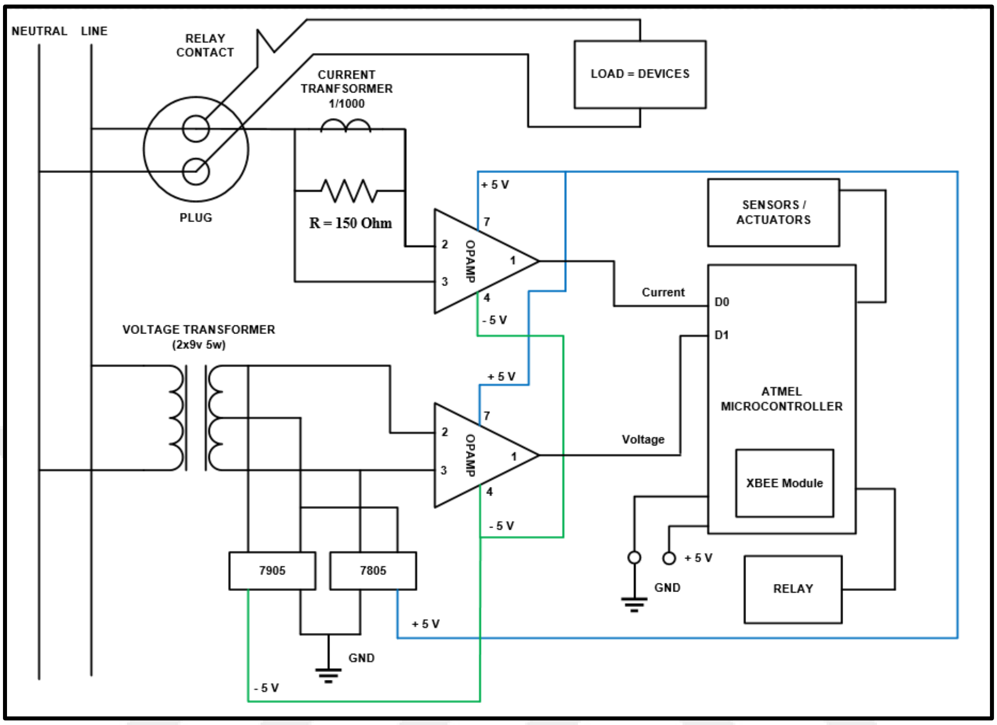


Figure 4.10. Smart Plug circuit design 1

The other method used in the project is to connect an XOR gate to the output of the OPAMPs. It is seen that there is a logic structure that gives 0 when the inputs are the same, and 1 when the inputs are different according to the truth table of the XOR gate. Since the aim of the power factor measurement is to find the difference between voltage and current, it is correct to use the XOR gate.

As long as the outputs of the OPAMPs are different, in other words, as long as there is phase difference between the voltage and the current, the XOR gate outputs the logic 1 output signal. This output signal, obtained from the XOR gate, is given to a digital input of the microcontroller and how long the incoming signal remains at logic 1 level is measured in the level of microseconds at which the incoming signal remains at logic 1 level by the microcontroller. Since it is known that the grid frequency is 50 Hz, it is found that 1 full pulse is 1/50 equals 20 milliseconds. Because of 1 full pulse is 360 degrees, 20 milliseconds corresponds to 360 degrees. In this case, if found duration in microsecond level is 20 milliseconds and 360 degrees, the calculations are made by proportioning. The power factor between the voltage and the current is found by taking the cosine of this angle. This method is preferred due to ease of programming, the proper fastness that is targeted for this project of XOR gate operation and ability to detect even small time differences. The measurement is performed during 1 second and the average of the measured values is taken and sent to the user. Designed circuit by using XOR is shown in Figure 4.11.

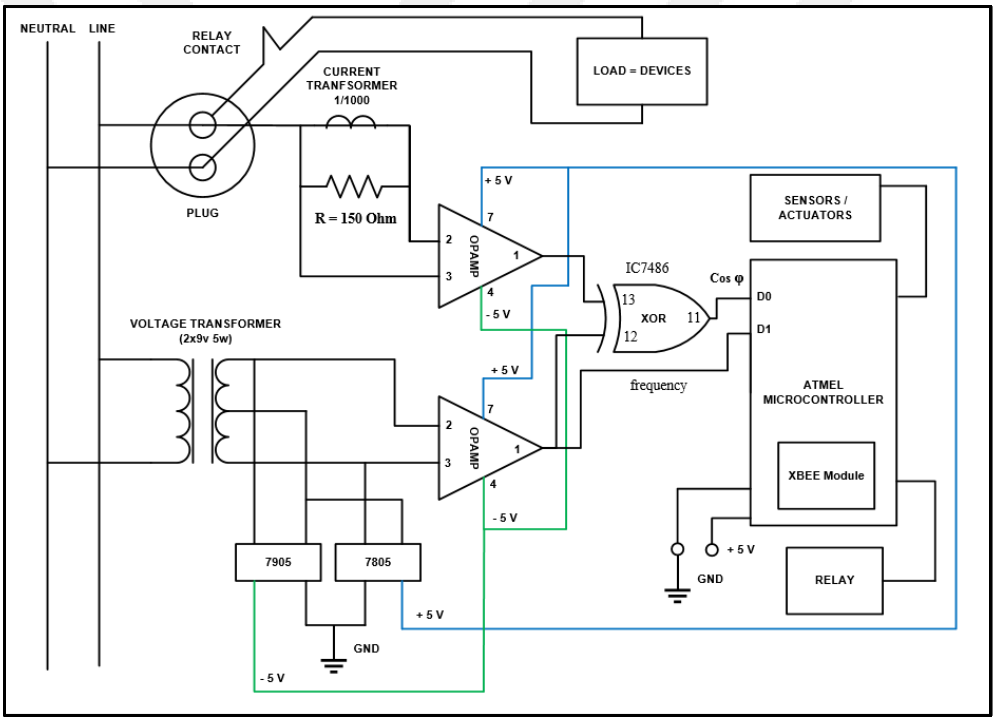


Figure 4.11. Smart Plug circuit design II

A power supply unit which supplies +/-5V DC to OPAMPs via the circuit that is designed for measurements, and supplies power to the microcontroller, other measurement devices and relays at the same time is designed. A transformer which gives 2 voltage outputs is chosen as step down voltage transformer. A 5W transformer is chosen considering the power requirements of symmetrical supply voltages, measurement sensors and other components. The bridge wave rectifier for rectifying and the pi type filter for filtering are used. 7805 and 7905 positive and negative voltage regulators which can regulate consistently are used for voltage regulation. It is prevented for obtained voltages to exceed +5 and -5V by these two voltage regulator.It is extremely important for fed power to be extremely linear and has the least noise because of demanding of power unit is a microcontroller, OPAMP and logic gates. In order to filter the noise that caused by regulators, the regulators are taken into pi type filters. Thus, it is possible to supply extremely linear and least noise power to demanding units. The final figure of the designed circuit with XOR is shown in Figure 4.12.

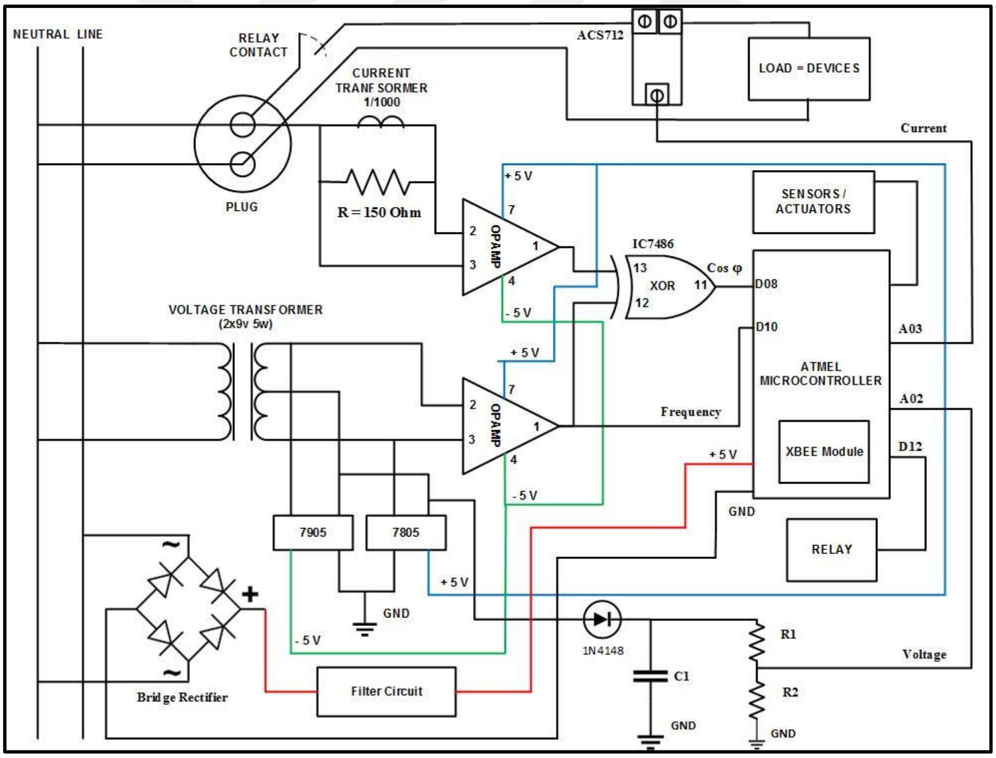


Figure 4.12. Smart Plug circuit design and implementation circuit

The selected circuit elements are assembled in according to calculations as shown in Figure 4.13. Application server software is developed following the connections that made between the designed circuit and the microcontroller card. It is provided to computer to read measurement results by the connection between embedded system software developed software and the embedded system to detect values entered to the computer. In addition, essential calibrations are made by test measurements of the designed circuit by means of this server software. Then it is connected to real load and monitoring and recording is started following the testing of process accuracy by a calibrated device.

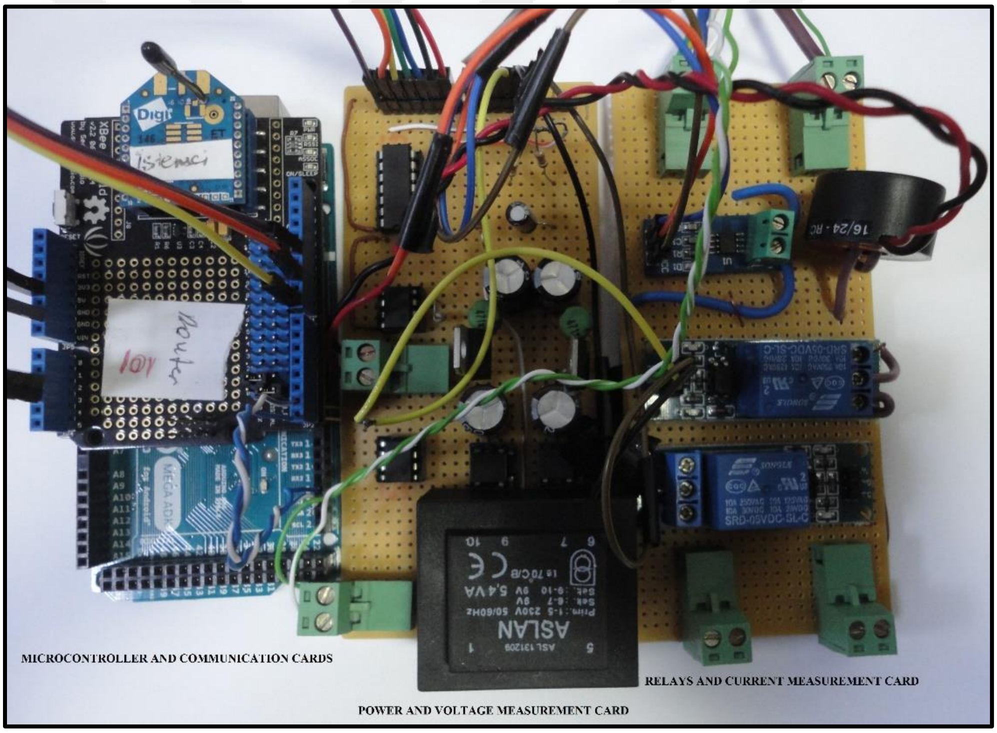


Figure 4.13. Realized Smart Plug circuit

The implemented smart plug design is tested on a 36-W fluorescent lamp circuit, fan and an electric stove that heats with resistance. Test results are shown in the table below. As seen on the table, it is observed that measurement is made with accuracy of 2% maximally.

Table 4.1. Comparison of values measured with SP and Hioki

	Smart Plug				Hioki 3334 AC/DC Power Tester			
	V	**I**	**Hz**	**cos φ**	**V**	**I**	**Hz**	**cos φ**
Fan	220.0	0.091	50.00	0.796	219.9	0.0930	49.97	0.784
	220.0	0.090	50.02	0.794	220.0	0.0920	50.00	0.784
	220.0	0.090	50.03	0.795	220.0	0.0920	50.01	0.785
	220.3	0.091	50.00	0.798	220.5	0.0918	49.97	0.785
	220.0	0.090	50.08	0.796	220.1	0.0917	50.02	0.785
Heater 1	216.1	3.35	50.01	0.997	216.0	3.318	49.96	0.997
	216.0	3.37	49.98	0.997	216.0	3.310	49.96	0.997
	216.1	3.35	49.98	0.998	216.0	3.312	49.97	0.997
	216.1	3.35	49.95	0.996	216.0	3.314	49.49	0.997
	216.0	3.35	50.12	0.997	216.0	3.312	49.99	0.997
Heater 2	213.2	6.55	50.03	0.996	213.2	6.54	50.09	0.997
	213.0	6.56	50.2	0.997	212.9	6.55	50.06	0.997
	213.1	6.57	50.15	0.997	213.3	6.56	49.98	0.997
	213.0	6.57	50.14	0.997	212.9	6.56	49.98	0.997
	213.1	6.57	50.12	0.997	213.3	6.56	49.99	0.997
Fluorescent Lamp	220.0	0.369	49.99	0.306	220.2	0.363	50.02	0.303
	219.7	0.363	49.99	0.325	219.8	0.359	49.99	0.32
	220.1	0.365	49.98	0.325	220.3	0.361	49.98	0.32
	220.5	0.350	49.99	0.333	220.7	0.346	49.97	0.329
	218.7	0.362	49.99	0.329	218.8	0.357	49.97	0.323

4.1.3. Summary

The smart plug was designed in the realized study and measured voltage, current, frequency, and cos φ values. Owing to these measurement values, power consumption was calculated. Two different electrical devices connected to the designed smart plug and checked the measurement values. This smart plug measurement values compared with the more sensitive measurement device. As a result, while the cos φ value measures, approximately 2% differential error was determined. DE can be corrected in the software code by using correction coefficient. In the future, this study can be improved to add new features. If desired, all data can be saved in a database and saved all values can be analysed by software writing codes.

4.2. Design and Implementation of AIRCON Control System

4.2.1. The Controlling of AIRCON

Air Conditioners (AIRCON) have been controlled by IR (Infrared) remote controls. If desired to control by using computer instead of the remote controller, IR codes must be read firstly. After the codes is read and the saved, recorded codes must be send to the AIRCON with IR transmitter. Because of this, realized project is consist of two parts mainly. First section is for receiving and second section is for transmitting. This implementation will be used for controlling of AIRCONs.

Realized project were written by using C# and ASP.Net. Desktop application was written by using C# in Microsoft Visual Studio. Web application was written by using ASP.NET in Microsoft Visual Studio. The main screen of C# and ASP.NET software have been shown in Figure 4.14. Although the two figures are similar in terms of appearance, the software codes and their components are different from each other.

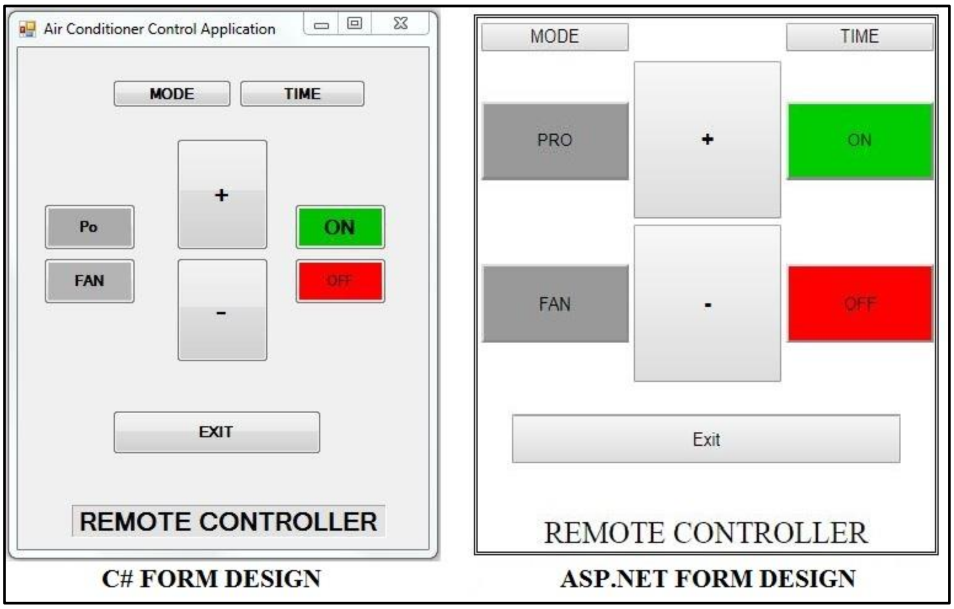


Figure 4.14. AIRCON remote controller form designs

4.2.2. The Live Checking Implementation in Empty Room

In this project, the time interval specified by the user, in room when presence detection the air conditioning switching off is to save energy via embedded system project.

It has been established using the Arduino Mega, fingerprint sensor, Panasonic Grid-Eye, IR receiver and transmitter sensor and the RTC module are used. The datasheets of whole used devices are shown in Appendix A. Designed circuit is shown in Figure 4.15. In this circuit, Panasonic grid eye sensor was detected while a person is in the room or not. If the room is empty and the time is after 5 p.m., AIRCON will be turned off automatically. The algorithm flowchart of the realized project has shown in Figure 4.16. This implementation will be used in the EMS of SBMS project for energy saving.

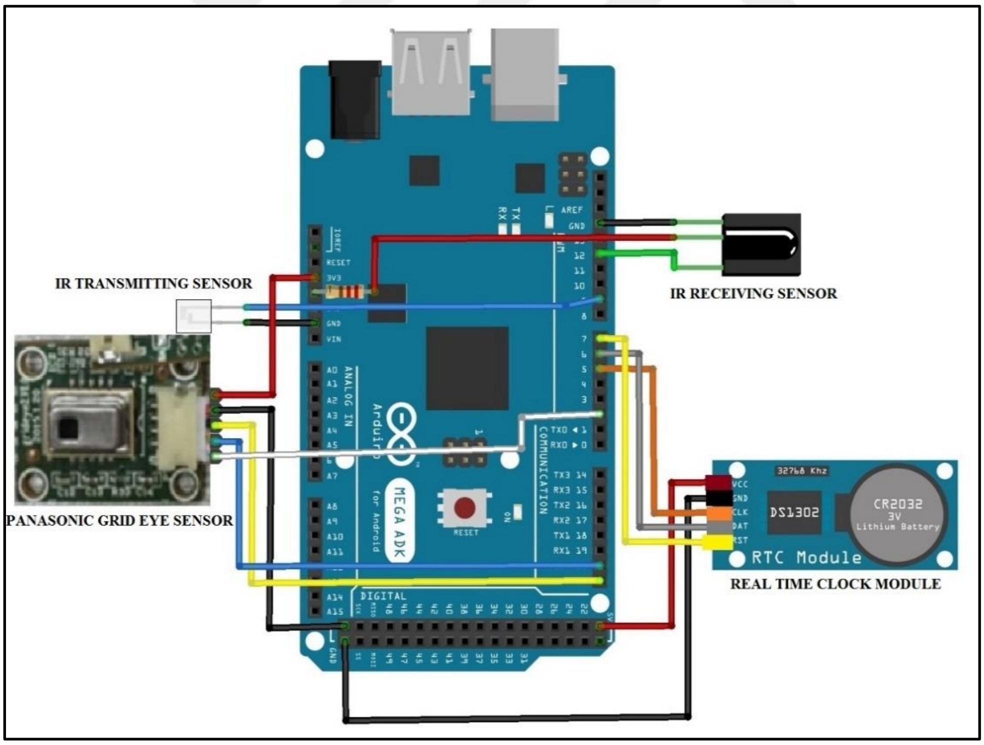


Figure 4.15. Empty room control circuit

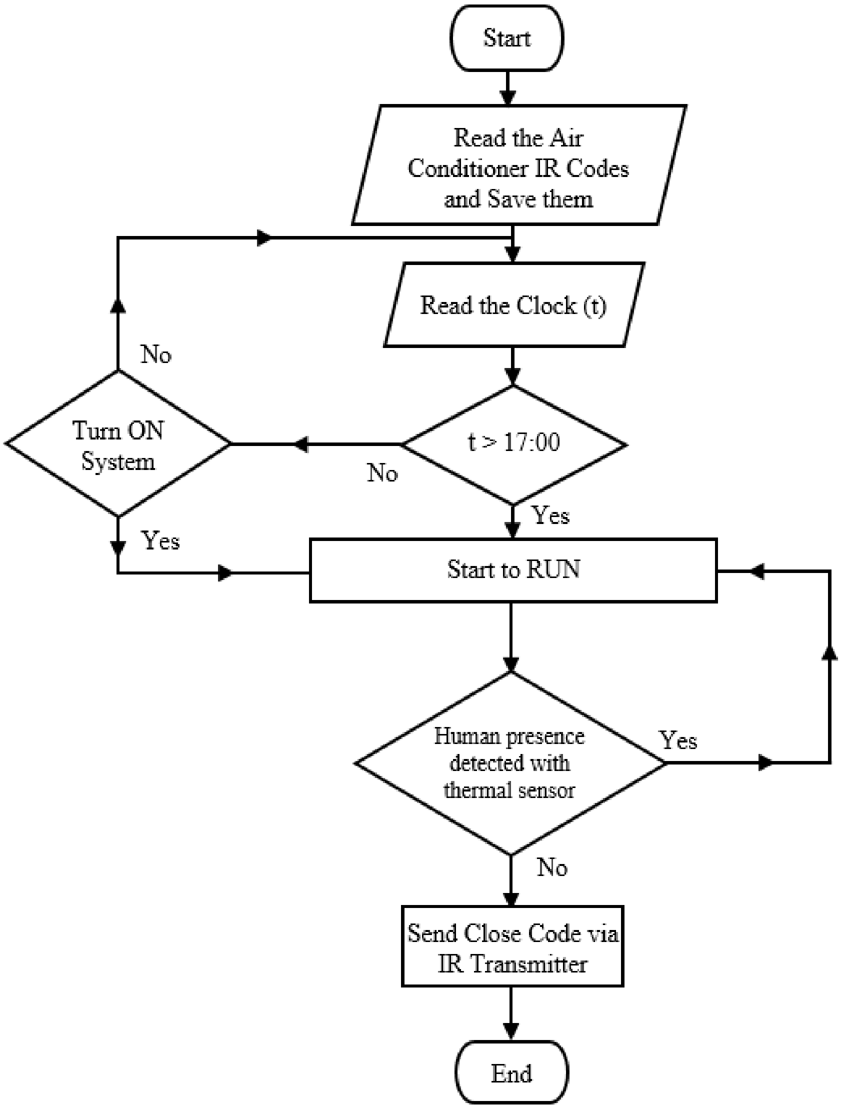


Figure 4.16. The algorithm flowchart of empty room control circuit

According to this algorithm, AIRCON IR codes are read from the AIRCON remote controller and saved them primarily. After that, CLOSE command is sent after 17:00 pm if there is no the live in the room. Thus, after the working hours, open AIRCONs will be automatically switched off.

In the realized project, printed wiring board has been designed as Arduino shield for for the installation of used electronic devices. The designed printed wiring board figure has been shown in Figure 4.17. In addition, the picture of whole realized project is given in Figure 4.18.

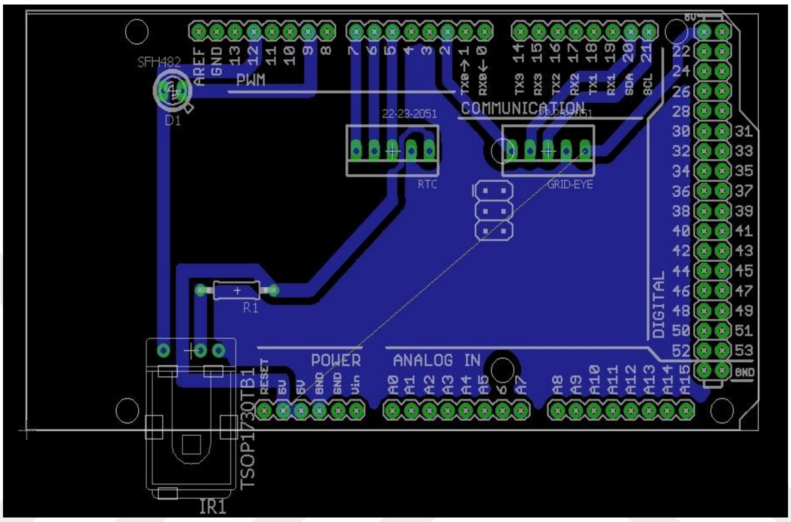


Figure 4.17. The printed wiring board of realized project

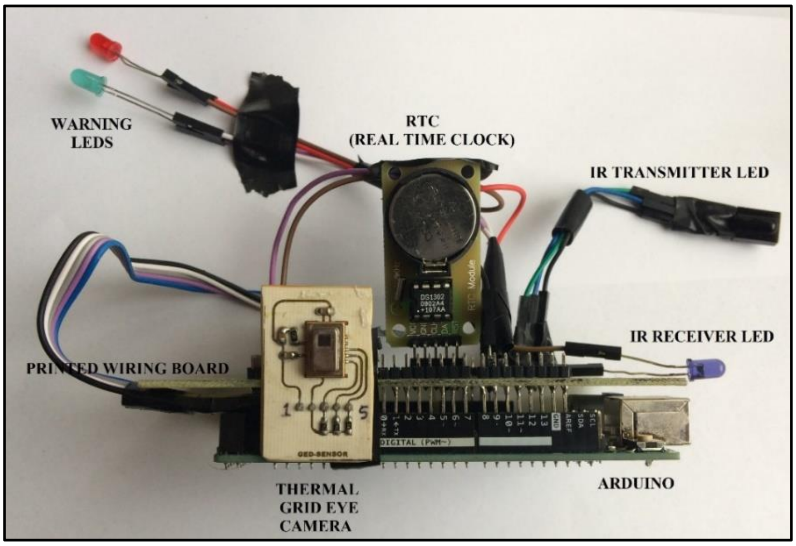
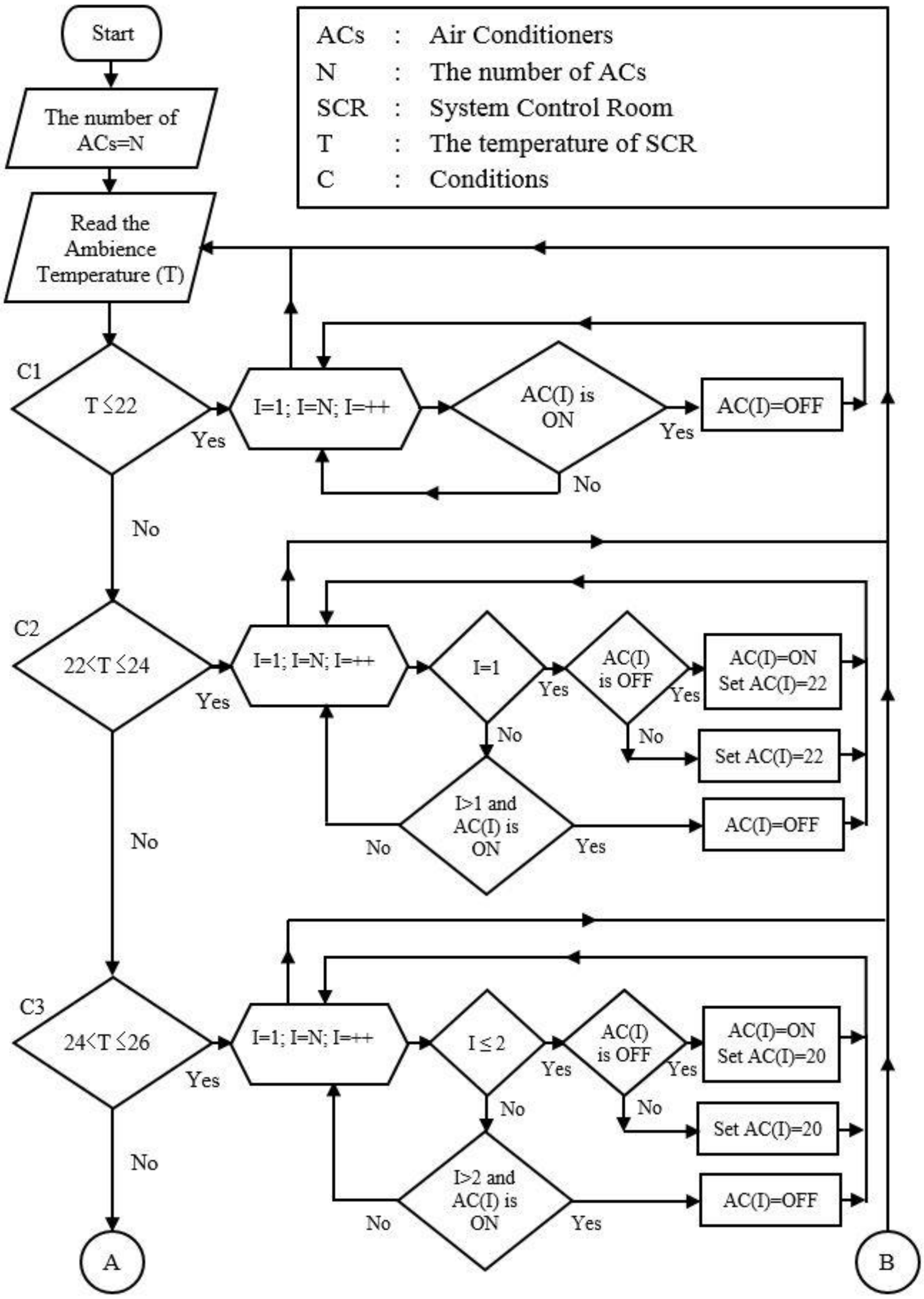


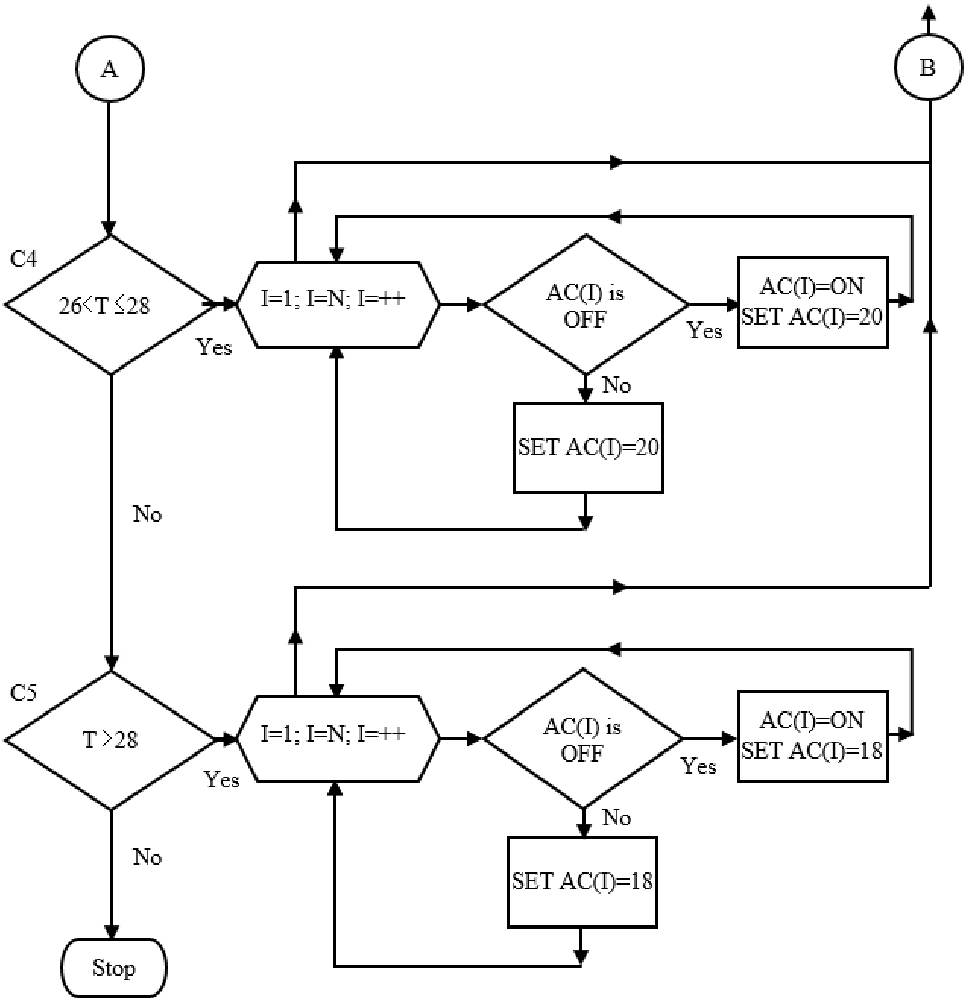
Figure 4.18. The picture of carried out empty room control circuit

4.2.3. Energy Saving Implementaion in Air Conditioners

In the System Control Room (SCR), there are three split type air conditioners (AIRCONs) which have without any speed control devices. These AIRCONs have been operated continuously for 7 days and 24 hours at the 22 ^{0}C temperature. Because AIRCONs have not a speed control device, all of them work by STOP and START logic. Thanks to thermistor on the AIRCONs, when the ambience temperature is arrived to the adjusted set value, the compressors of the AIRCONs are stopped automatically. When ambience temperature changes again, all compressors start to run again. An electric motor consumes maximum energy while it starts to run at the first time. The more the number of stops and starts, the greater the amount of electricity consumption that it will increase. Nowadays, in order to prevent this situation, AIRCONs with speed control devices are used. Since the AIRCONs in the SCR do not have speed control devices and speed controller can not be installed to these existing AIRCONs, it has been aimed to save energy in the current AIRCONs by this realized project.

In the realized project, conventional old AIRCONs were operated such as AIRCONs which have speed control devices. Whole AIRCONS own the same trade mark and model. This situation provides some facilities such as the using of same IR code, management with same microcontroller. In addition to previous realized project, temperature sensor has been added in this project to measure ambience temperature and the grid eye sensor has been removed from the circuit because no asset detection is required. According to measured ambience temperature, AIRCONs increase or decrease their own temperature value. Moreover, if all AIRCONs do not need to work at the same time, AIRCONs will be shutted down respectively. If the AIRCON is needed to adjust the ambient temperature, the system will automatically activate the AIRCON as needed. Realized study is not only supported at the AIRCONs in the existing SCR but also designed to manage the desired the numbers of AIRCONs at the same time. The flowchart of carried out algorithm is shown in Figure 4.19.


Start
The number of ACs=N
Read the Ambience Temperature (T)
ACs : Air Conditioners
N : The number of ACs
SCR : System Control Room
T : The temperature of SCR
C : Conditions
C1
T ≤22
Yes
No
I=1; I=N; I=++
AC(I) is ON
Yes
No
AC(I)=OFF
C2
22<T ≤24
I=1
AC(I) is OFF
AC(I)=ON Set AC(I)=22
Set AC(I)=22
I>1 and AC(I) is ON
AC(I)=OFF
C3
24<T ≤26
I ≤ 2
AC(I)=ON Set AC(I)=20
Set AC(I)=20
I>2 and AC(I) is ON
A
B



Conditions:

C1. Close the all open ACs
C2. Open the first AC and set it 22^{0}C, Close the other ACs
C3. Open the first two ACs and set them 20^{0}C, Close the other ACs
C4. Open the all ACs and set them 20^{0}C
C5. Open the all ACs and set them 18^{0}C

Figure 4.19. The flowchart algorithm of AIRCON management system

Primarily, with the SBMS software and application of the smart plug developed within the scope of the project, total energy consumption of existing AIRCONs has been measured for a week. Later, AIRCON management system has been activated and same measurement, with the same software and the same smart plug, has been realized again. The studies were carried out in December. Energy consumption were measured by SMBS software as approximately 1,008 KWh for whole AIRCONs. When the AIRCON management system is active, nearly 706 KWh total energy consumption for whole AIRCONs was also measured.

As a result of realized measurements, it was determined that approximately 30% energy saving was performed by using AIRCON management system. This means that one of the three AIRCONs is working unnecessarily in December.

4.3. Design and Implementation of Lighting Control

Different types of lamps are used in different sectors such as commercial and residential buildings, industrial sector, health sector, and forth. Lighting has an important place in terms of electricity consumption. In order to save energy in lighting, various methods are developed. The most preferred methods are replacing of old conventional lamps with the new saving lamps, using of occupancy, daylight, or timers, and dimming of the lamps.

4.3.1. LED Dimming

LED Dimming can be realized three different methods. One of them is to use resistance. The one of two different methods is to use DC voltage which can be adjustable from 1V to 10 V DC. The last method is to utilize from PWM signal. While the LED lamps are dimmed, one of these three methods can be used easily.

The circuit which has MOSFET is used as shown in Figure 4.20 for the LED dimming MOSFET controls the LED current via voltage which comes from Arduino analog output A9 pin. A9 output pin has voltage value range between 0V and 5 V.

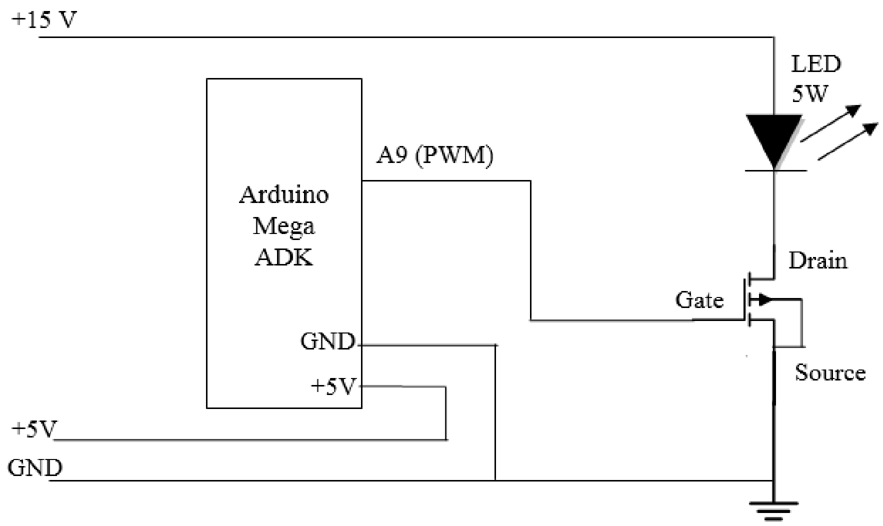


Figure 4.20. LED dimming circuit realized by using MOSFET

With the arduino PWM voltage, gate voltage of MOSFET can be increased or decreased. Thus, Gate voltage controls the drain-source current. When the current which passes through the LED increases, lighting intensity will increase proportionally. When current decreases, LED lighting intensity will decrease too.

The dimming process can be carried out with dimmable LED driver instead of using MOSFET. The use of MOSFET instead of a dimmable drive will be much more logical if it is considered as financially. A MOSFET is very cheaper than a LED driver. When the comparison of MOSFET and LED driver is carried out in the view of efficiency, LED driver is superior to MOSFET. When a project is implemented, the comparison of efficiency and financial status have to be carried out.

In the realized SBMS project, both MOSFET and LED driver have been used for different applications. MOSFETs were used in prototype studies and trial runs especially. LED drivers instead of MOSFET were preferred in real studies and main SMBS projects. Prototype realization, trial works, and realized projects have been presented follow paragraphs.

4.3.2. LED Control by using Bluetooth and MIT App Invertor 2

Before the main SBMS application are realized, communication methods, microcontroller cards, software languages, database servers, operating systems, and many more topics should be investigated in detail. Because of this, many methods and devices has been tried. One of them is Bluetooth communication protocols and Bluetooth devices.

Bluetooth module, is named HC06, has been investigated to use at the all applications. This connection module can be used for the short distance up to 8-10 meters wireless applications. Firstly, the connection between arduino and HC06 bluetooth module was realized. And then HC06 was defined by using arduino codes as shown in Appendix A. HC06 has four pins for connection. Two of four are for power VCC and GND (ground) pins. Other two are used for receiving (RXD) and transmitting (TXD) data. The HC06 communicates as a serial ports. Either serial terminal programs such as Putty etc. or serial connection component in software development engine should be used.

After the selection of moduel, the writing of android application has been aimed. Because of this, android writing development software were investigated. Java and Android Development Studio programs are quite complex. When App Invertor 2 which is developed by the Massachusetts Institute of Technology compares with other development platforms, it seems to be very useful and simple. App Inventor for Android is an open-source. Open source means that it is a free program. In this platform, some blocks which are similar to puzzle blocks have been used instead of code lines. Because of this, the possibility of making the user's fault has been minimized automatically. In this realized project, LED ON/OFF software were written by using App Invertor 2 firstly. This code blocks are shown in Figure 4.21.

As shown in figure, codes are consist of four main grup. First two blocks are used for bluetooth connection. Other two blocks are also used for ON/OFF buttons. As shown in this block parts, it is not possible to connect wrong parts.

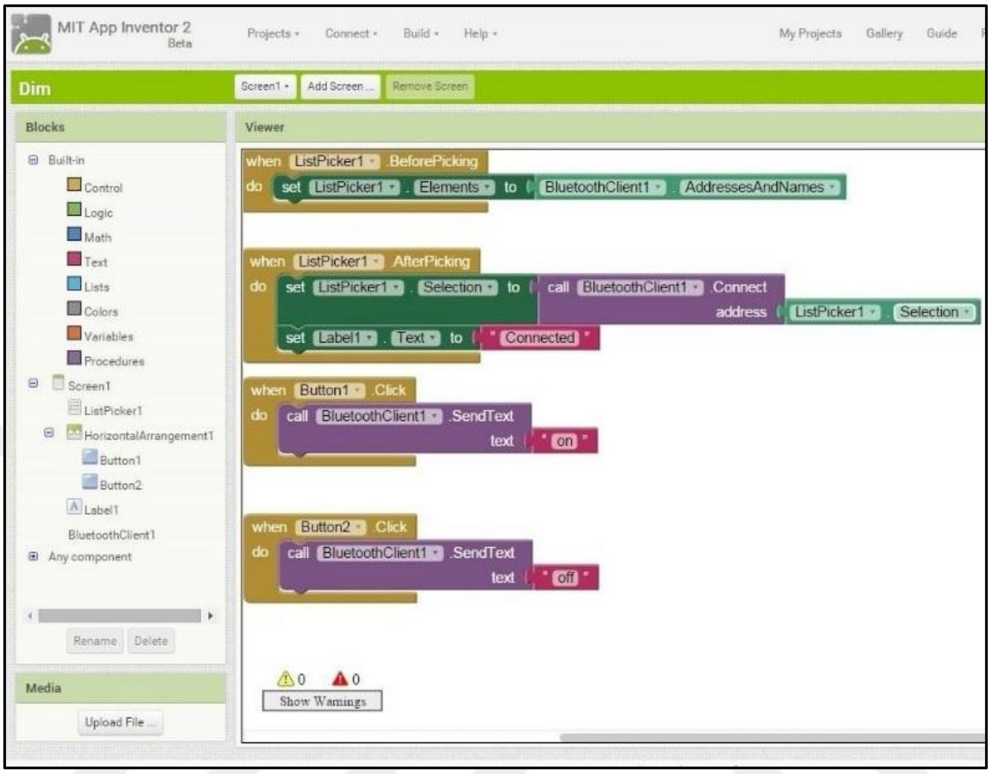


Figure 4.21. MIT App Inventor Version 2 Android development software

According to written blocks, user screen form must be prepared as shown in Figure 4.22. This screen has three main buttons. One of them is used for selection of bluetooth devices. Other two buttons are used to turn on/off LED lighting.

In this study, MIT App Invertor 2 and Bluetooth communication module were tested. When the MIT App Invertor 2 compares to other professional software such as Java, Android studio, RAD studio, and so forth, it has been understood that MIT App software is very simple. However, during the investigation, it has been shown that professional softwares instead of MIT App Invertor 2 software are preffered in the realized projects. The use of code writing instead of puzzle blocks provides more flexible writing facility.

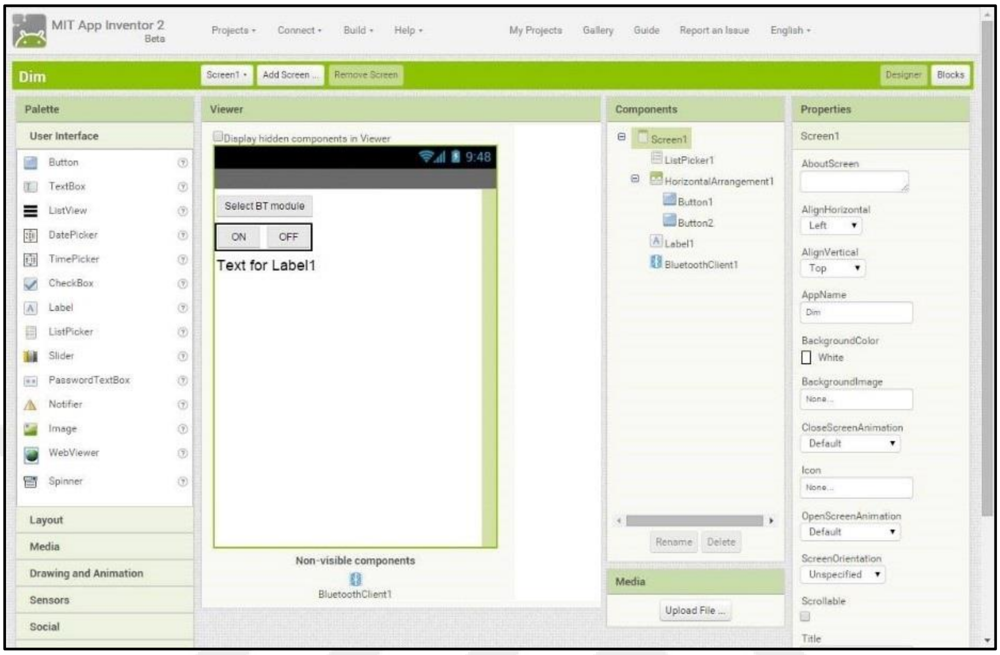


Figure 4.22. MIT App Inventor 2 user screen

4.3.3. LED and Relay Control by using Bluetooth and RAD Studio

Although MIT App Inventor 2 Android Software Development Platform is suitable for educational and amateur projects, more advanced software development platform must be used for more complex and professional projects. Java, Android Studio and RAD studio programs were investigated for android software develoment. RAD studio written by Embercarado was preferred to able to write desktop, linux and mobile software at the same time. After a program is written by using the RAD studio editor, it can be compiled according to desired operating system such as Windows desktop, Linux, MACOS, and Android. If desired, after written software are compiled to windows desktop software, it can be converted into Web applications by using some utilities.

After the RAD studio based on DELPHI is selected, realized LED Control project in previous section has been improved again by using RAD studio. In addition to first project, Bluetooth connection section and relay control section has added to this project. Realized project by using RAD studio has been shown in Figure 4.23. This software has been written by Delphi section of RAD studio. While software is compiled, Android devices should be selected as compiled environment.

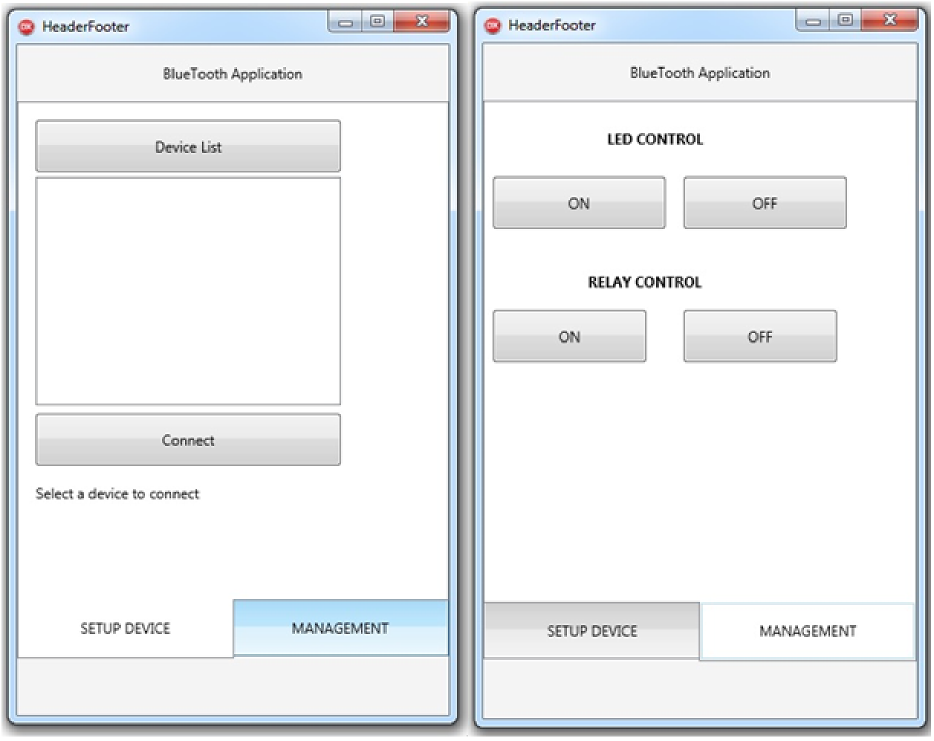


Figure 4.23. LED and Relay control by using Bluetooth in Android platform

At this program, LED and Relay have controlled with a mobile phone or tablet via Bluetooth as wireless. This software is consist of two sections. First section is used for the connection of bluetooth device and the second section is used for controlling of the LED lamp and relay. Before the controlling of LED lamp and relay section, mobile device which has Android software should be selected from Device List in Setup Device tab. After the connection of mobile device via Bluetooth, LED and Relay controlling can be operated.

4.3.4. LED Dimming Project in Corridor

The replacing of old inefficient lamps with the new saving lamps such as LED provides energy saving. In order to increase energy saving amount, using of occupancy sensor, daylight sensor, motion sensor, timers, and dimming methods are the most preffered methods.

In the realized project, the dimming of the LED lamps used for corridor illumination was accomplished with the help of motion sensors. 5 LED lamps with 5W and 5 motion sensors were used in this project. Thanks to developed algorithm, if desired, these numbers can be increased. The developed algorithm supports the desired number of lights.

Developed algorithm in the realized project is explained step by step in the following lines

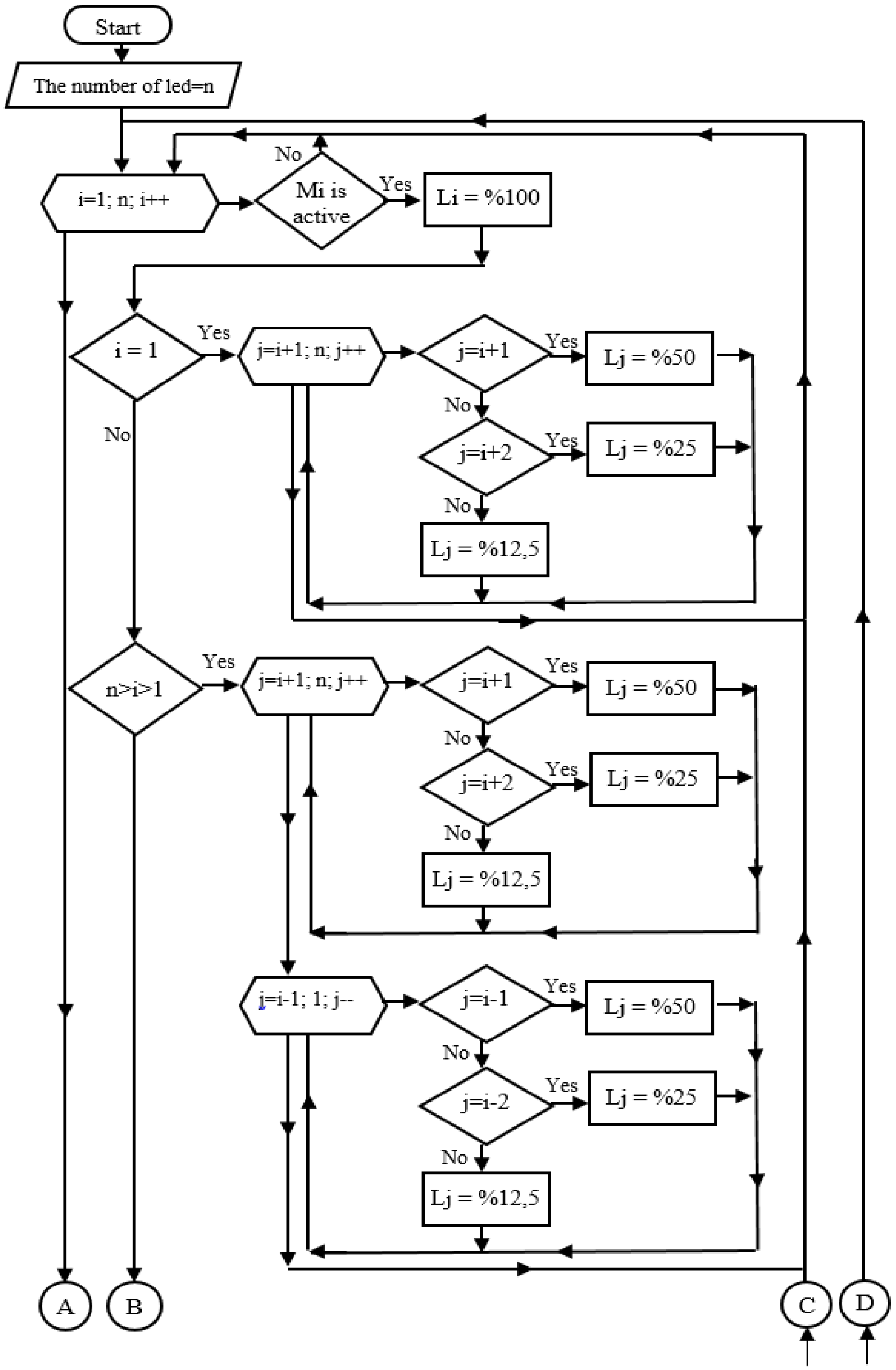
- **Algorithm Steps**
  1. Start
  2. Enter number of leds = n (each led has its own motion sensor(**m**) so number of sensor = n)
  3. For (i=1;n;i++) loop starts from 1 up to n increasing by 1 and detects all the sensors if active or not
     a. If **m**i is active then lighting of led(i) = %100
     b. Else go step 3
     c. If i=1 then the new loop starts to control the forward leds's lighting gradually
        i. For (j=i+1;n;j++) j starts from i+1 up to n increasing by 1
        ii. If j=i+1 then lighting of led(j) = 50%
        iii. Else if j=i+2 then lighting of led(j) = 25%
        iv. Else then lighting of led(j) = 12.5%
        v. When j=n+1 then loop ends and returns to first loop (step 3)

d. If n>i>1 then two loops work one after another to control the forward leds's and posterior leds's lighting gradually
   i. For (j=i+1;n;j++) j starts from i+1 up to n increasing by 1
   ii. If j=i+1 then lighting of led(j) = 50%
   iii. Else if j=i+2 then lighting of led(j) = 25%
   iv. Else then lighting of led(j) = 12.5%
   v. When j=n+1 then loop ends and goes to new loop which controls the posterior leds's lighting gradually
   vi. For (j=i-1; 1; 1--) j starts from i-1 back to 1 decreasing by 1
   vii. If j=i-1 then lighting of led(j) = 50%
   viii. Else if j=i-2 then lighting of led(j) = 25%
   ix. Else then lighting of led(j)= 12.5%
   x. When j=0 then loop ends and returns to first loop (step 3)

e. If i=n then starts new loop to control the posterior leds's lighting gradually
   i. For (j=i-1; 1; 1--) j starts from i-1 back to 1 decreasing by 1
   ii. If j=i-1 then lighting of led(j) = 50%
   iii. Else if j=i-2 then lighting of led(j) = 25%
   iv. Else then lighting of led(j)= 12.5%
   v. When j=0 then loop ends and returns to first loop (step 3)

4. When the first loop ends then main loop will be started again or it will be ended.

As can be understood from the algorithm steps, energy saving rate is depend on whether motion is sensed or not. When motion is sensed, lighting amount will increase and if there is no motion, all LED lamps will run at 12.5% rate. In addition to algorithm steps, the flowchart of the algorithm has been shown in Figure 4.24.


Start
The number of led=n
i=1; n; i++
Mi is active
No
Yes
Li = %100
i = 1
Yes
No
j=i+1; n; j++
j=i+1
Yes
Lj = %50
No
j=i+2
Yes
Lj = %25
No
Lj = %12,5
n>i>1
Yes
j=i+1; n; j++
j=i+1
Yes
Lj = %50
No
j=i+2
Yes
Lj = %25
No
Lj = %12,5
j=i-1; 1; j--
j=i-1
Yes
Lj = %50
No
j=i-2
Yes
Lj = %25
No
Lj = %12,5
A
B
C
D

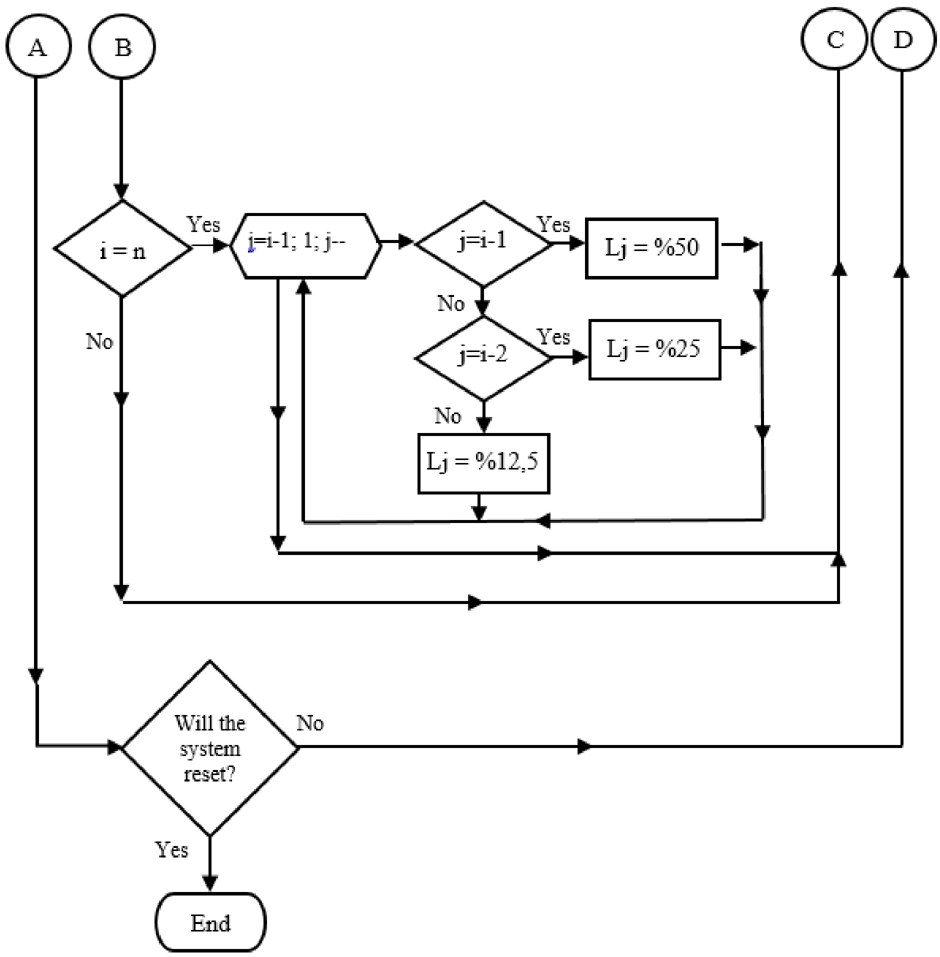


Figure 4.24. The flowchart algorithm of LED dimming circuit

When the system is activated, daily measurements have been made for a week. The amount of savings obtained varies from 8% to 20%. Energy saving amount was depending on the number of people. As a result of the LED dimming implementation the obtained average energy saving amount was approximately 14%. Existing project has been activated manually after 17:00 pm but if desired, LDR or daylight sensor can be added to develop this project.

4.4. Design and Implementation of Solar Tracking System

Solar energy has been improving rapidly. It takes noticeable place as an important means of expanding renewable energy sources. The PV array gives different output at different time of day for different orientations depending upon the amount of sunlight falling on the module and on the angle at which rays fall on it. Thus the angle at which the module is placed with respect to the ground can be optimized so as to obtain maximum output from the module at all time. Solar tracking systems allows more energy efficiency for following the sun movements. In the realized project, solar panel tracking system is going to be developed by using Arduino Mega ADK microcontroller.

The main purpose of the project is to achieve maximum possible output from the solar panel at all times of day. This is achieved by studying multiple power point tracking techniques. Then the panel will be rotated in horizontally axis to function in a proper orientation.

There are two types of tracking system. One of them is passive tracking system and the other is active tracking system. Passive Tracking Systems one possible option for tracking is a chemical/mechanical system. This system uses the idea of thermal expansion of materials as a method for tracking. Typically a chlorofluorocarbon or a type of shape memory alloy is placed on either side of the solar panel. When the panel is perpendicular with the sun, the two sides are at equilibrium. Once the sun moves, one side is heated and causes one side to expand and the other to contract, causing the solar panel to rotate. A passive system has the potential to increase efficiency by 23%. These systems are far cheaper than active systems (Catarius and Christiner, 2010).

Active trackers use motors and gear trains to direct the tracker as commanded by a controller responding to the solar direction. In order to control and manage the movement of these massive structures special slewing drives are designed and rigorously tested.

In the realized project, active tracking system has been used. This thesis has presented a means of controlling a sun-tracking array with an embedded microcontroller system. Specifically it demonstrates a working software solution for maximizing solar cell output by positioning a solar array at the point of maximum light intensity. This project presents a method of searching and tracking for the sun.

4.4.1. Definition of Used Devices

The materials and their technical specifications which is used in realized project has shown in Figure 4.25 and Appendix A.

Figure 4.25. Horizantal axis photovoltaic solar panel and stepper motor

As shown in Appendix A, Stepper motor has worked by 24 V dc voltage. When the stepper motor connects to dc voltage directly, it will rotate one direction. If the motor direction is wanted to be changed, the direction of dc voltage must be changed. In order to manage stepper motor and motor direction, Quadruple relay card has been used. Besides, LDR (Light Dependent Resistor) has been used for measuring of light amount. Acording to measured light amount, stepper motor will rotate either left or right. Thanks to RTC (Real Time Card), working time of the system will be determined. After the sun sets, it is ridicilous the working of this system. That's why RTC is used. In addition to all devices, 16x2 LCD (Liquid Cyristal Display) is used for time and LDR light amounts. The circuit diagram of realized project has been shown at Figure 4.26.

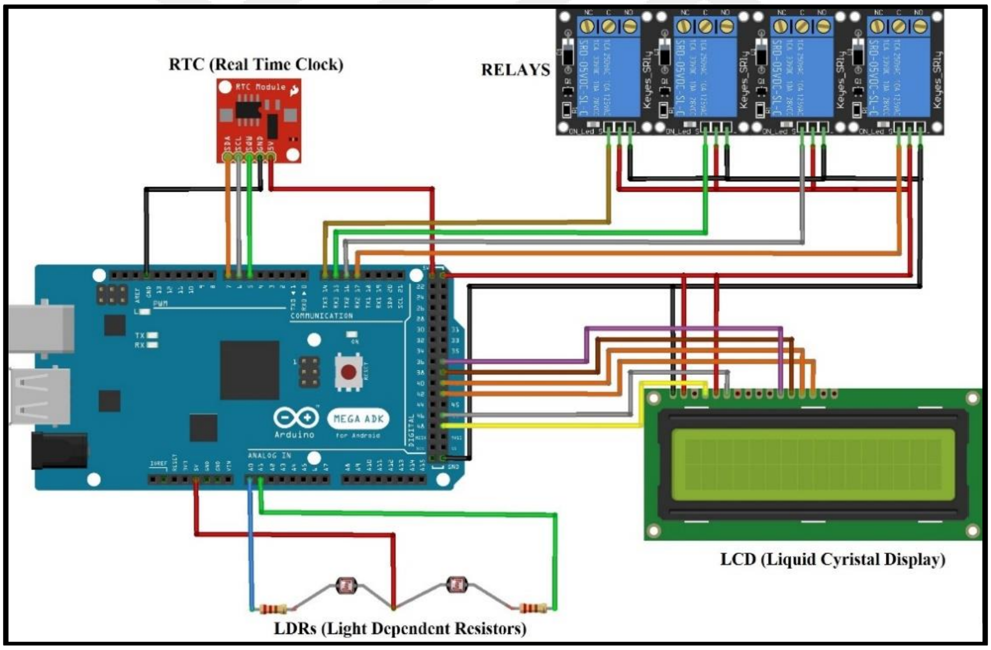


Figure 4.26. The circuit diagram of PV solar tracking system

4.4.2. The Explanation of Working Principle of System

The working principle of solar tracking system can be explained by helping of algorithm in Figure 4.27 briefly.

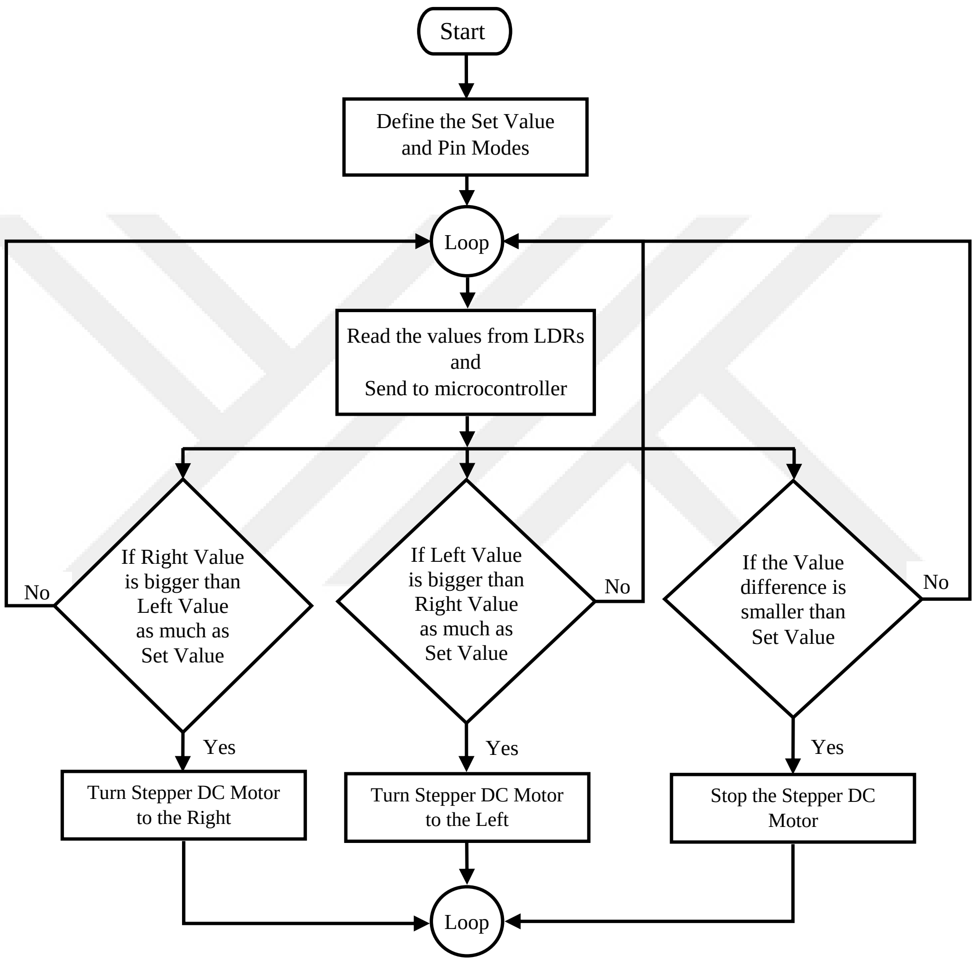


Figure 4.27. Flowchart of solar tracking system codes

In order to measure light intensity, two units of LDR are used. One of them is installed at the left up corner of PV panel and the other is also mounted at the right up corner of the PV panel. When the sun rises in the morning from the east, LDR sensor at left will take more light than LDR sensor at right side. In this situation, stepper motor will turn to left sides. As time progresses, the sun will act to west. In this case, light intensity of right sensor will be bigger than light intensity of left sensor. Because of this, stepper motor will turn to right. When the light intensities are close to each other, PV panel will remain motionless. Embedded codes can be operated either by itself or by using of developed SBMS software. As a result of all these studies, the following circuit shown in Figure 4.28 has been realized.

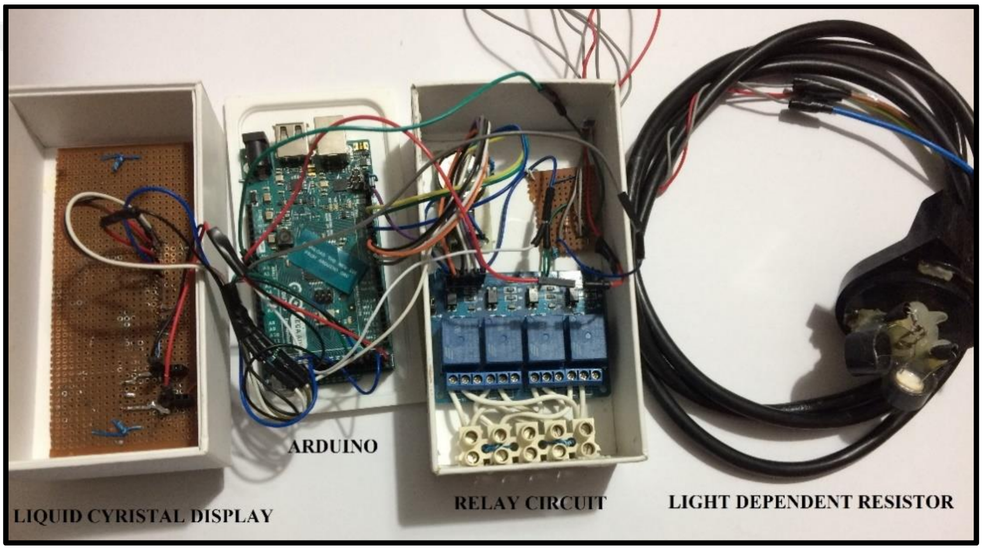


Figure 4.28. Realized project of solar tracking system

5. DESIGN AND IMPLEMENTATION OF SCS

In the security section, door security of system control room (SCR) was designed. This section consists of three main sections as “Door security with keypad”, “Door cecurity with fingerprint sensor”, and “Remote control with IP camera”. These three projects, which were realized, were put into action together with the aim of safe entry into the SCR. The realized project is carried out briefly as follows:

If somebody requests to go into SCR after 5 pm, correct password have to be entered by using keypad or his/her fingerprint information should be matched the previously recorded fingerprint. Otherwise, buzzer will run and the short message service (SMS) will be activated and a short message will be sent to the authorized or responsible person.

Realized project will inform the authorized staff via SMS in case of unauthorized access. In the case of unauthorized access, the authorized staff need to monitor the room from remote to see what is going on. When responsible person takes the SMS, he/she can be controlled whether someone goes into the system control room without permission with his/her android phone. If someone who goes into SCR knows the login password, he/she can enter password with the keypad and can stop the buzzer alarm. If login password is unknown, alarm sound and sending SMS will continue periodically. In this study, android application was developed to monitor the room remotely as alive and video screaming by using android software

In the SBMS software, projects carried out in this section are combined and the events during logging are saved in log files. The information of the logged-in persons during login was saved along with the date and time information and stored in the database file. Moreover, the embedded fingerprint and password information on the microcontroller cards was also stored on the database tables. Consequently, the realized system was either run on embedded cards by itself or with the help of SBMS software in a computer.

5.1. Implementation of Door Security System with Keypad

SCRs which have high cost products or service outputs such as main servers, database storages, and vital data are made up of very high cost equipments. A failure with some of this equipments would cause loss of money and resources. Due to this fact, these kind of equipments are isolated from the working areas and located at rooms with restricted entries. In order to ensure the restricted entry, a door alarm can be used. But it would not help if the room is located at a place that no one can hear the alarm from it. Remote information system should be installed to solve this problem. In order to solve similar problems, in the realized project, authorized staff will be informed in case of unauthorized access. One of the purposes of this study is to develop a system that will inform the authorized staff via SMS in case of unauthorized access.

The door security system includes a magnetic contact which generates a signal to indicate if the the door is open or closed. Arduino MCU receives this signal and asks the user to enter the password if the door is open after 5 p.m. If the password is not entered correctly in three times, the system informs the authorized staff and sounds an alarm. An android application to let the user to connect the user interface of the IP camera of the control room after receiving "Unauthorized access" message.

At the scope of realized project, IP Camera, Arduino Mega ADK, GSM/GPRS module, RTC (Real Time Clock) module, Keypad, LCD (Liquid Crystal Display) screen, buttons, buzzer and magnetic contact were used. Used hardwares and their technical features are given in Appendix A.

Arduino Mega ADK card is used as a microcontroller in realized project. It is the brain of the project. It controls all input and output pins. Furthermore, it manages all software lines.

The GSM Shield allows Arduino board to make phone calls, send SMS and connect to the Internet. It is used for a special language which is called «AT Commands» to communicate with the GSM Shield. A sample of the AT

Commands is shown as Table 5.1. The first part of sending SMS codes is used for calling SendTextMessage function and the second part of codes is used for sending text via AT Commands. These commands are obtained from the datasheet updates in 2010 of the SIM900 on the GSM card. SIM900 module is manufactured by SIMCON.

Table 5.1. AT Commands to send a text message

Command	**Response**
AT+CMGF=<mode><CR>	OK
AT+CMGS=<number><CR><message><CTRL-Z>	+CMGS:<mr> OK

RTC (Real Time Clock) Module is used for perception of time. DS1302 is an integrated circuit that counts the date and time after an initial count. It gives current information about date and time at needed any time.

For the entering of the password, Keypad is used. Keypad Keypad is a device to get informations from users at security systems, menu selection or embedded systems applications. General definitions of Keypad are realized as library, password set, rows and columns of keypad, keypad characters. Finally keypad pin connections are carried out. When somebody presses a key on the keypad, the microcontroller will perceive pressed key by the help of these code lines. Codes are used for receivind pressed key data and verifying entered password. Whether entered codes are correct or not should be controlled.

In order to monitor the entered password, LCD (Liquid Cyristal Display) Screen is used. At the realized project, 2x16 LCD Screen was used to print required messages for user. The other used components of realized project are buzzer, button and magnetic contact. Realized door security system and its prototype picture are shown in Figure 5.1 and Figure 5.2 respectively.

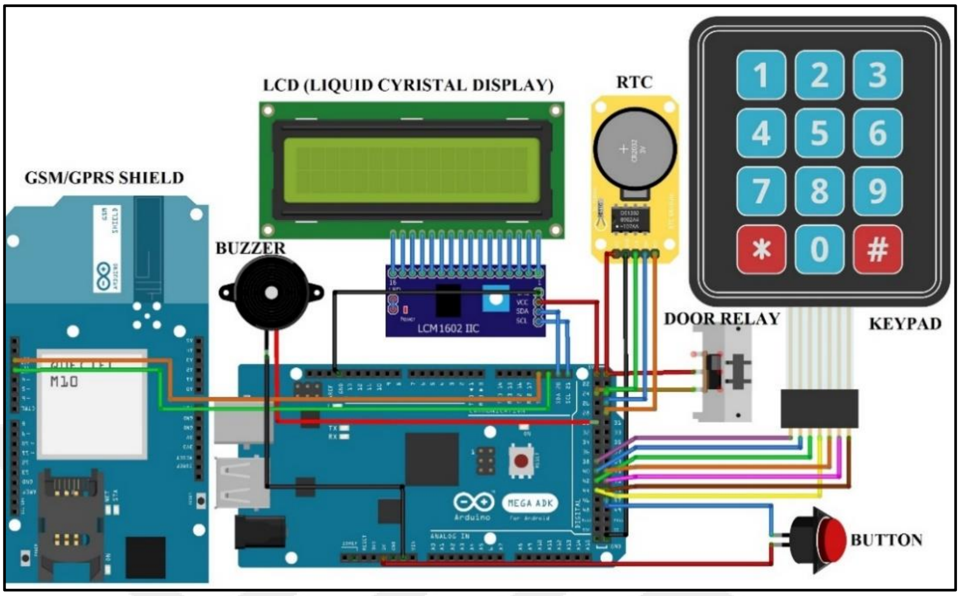


Figure 5.1. The circuit of door security system with keypad

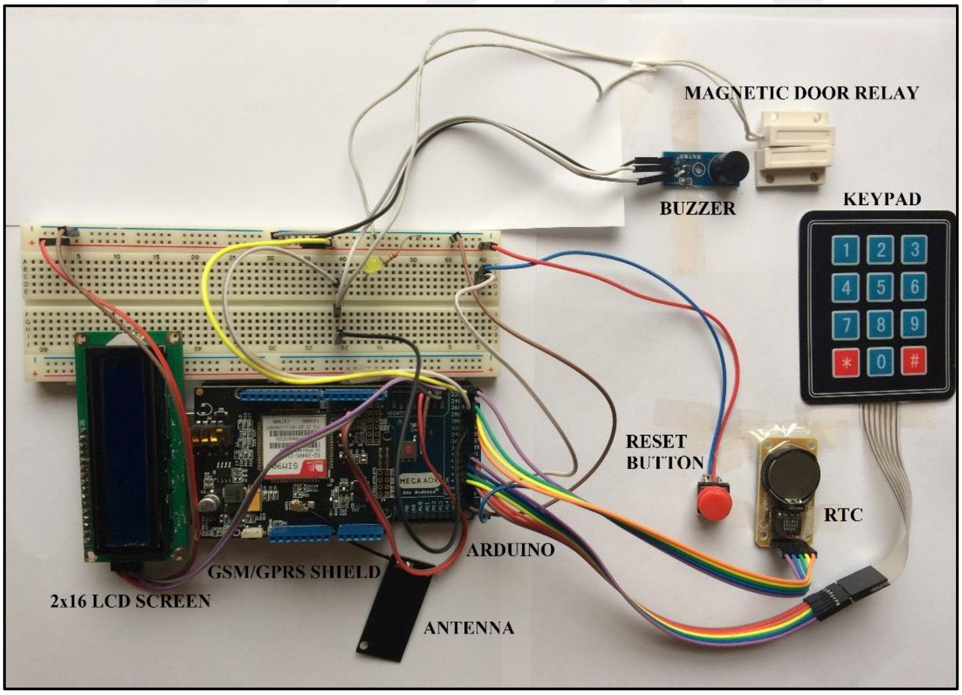


Figure 5.2. Realized project prototype of door security system with keypad

The algorithm flowchart of door security system with keypad is shown in Figure 5.3 in full detail.

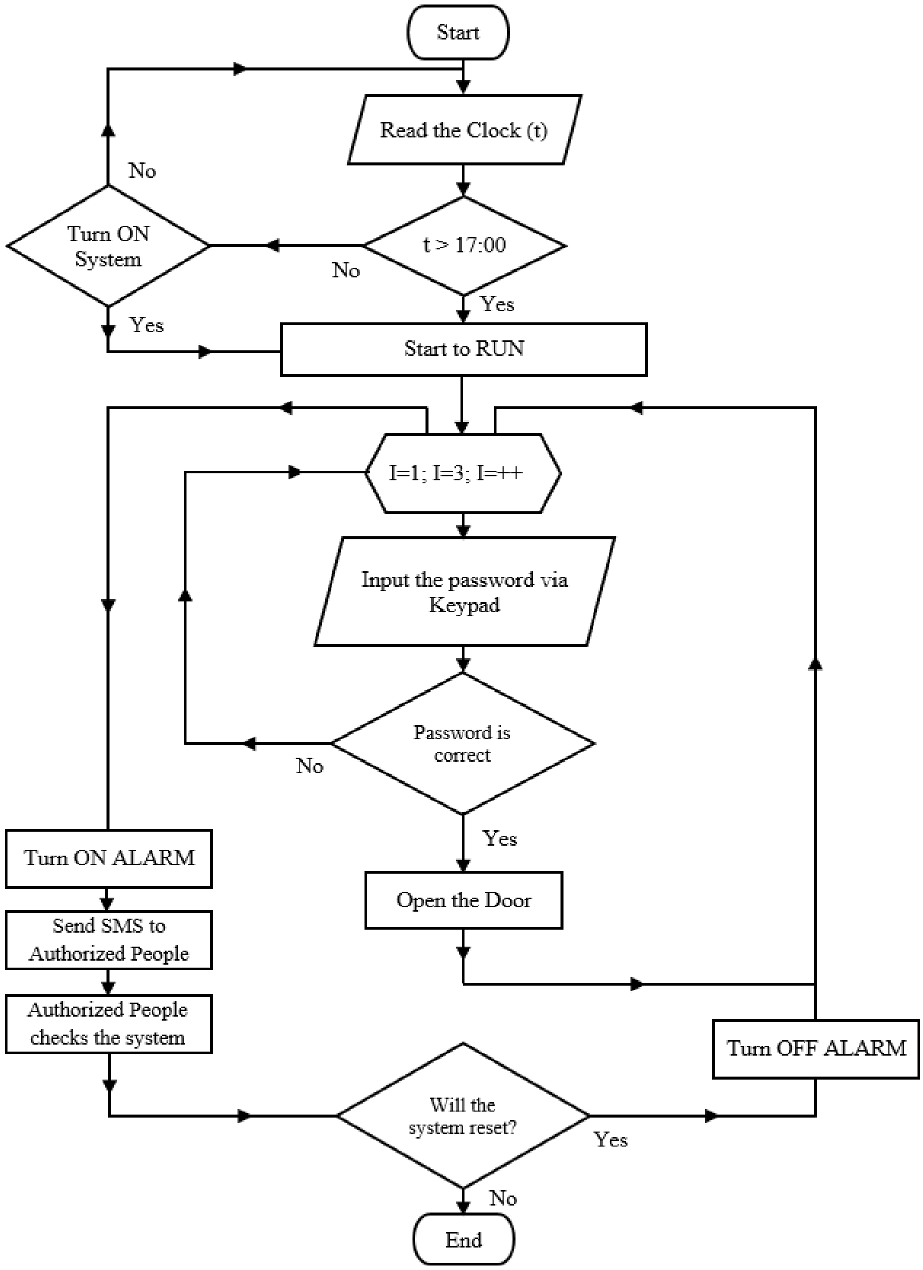


Figure 5.3. The algorithm flowchart of door security system with keypad

5.2. Implementation of Door Security System with Fingerprint Sensor

In the second section of door security system, fingerprint sensor was used for providing of SCR security. The fingerprint sensors are an optical sensors and they use for detecting and verification of fingerprints. According to fingerprint sensor datasheet shown in Appendix A., new fingers can be enrolled directly and furthermore, up to 162 finger prints can be stored in the onboard FLASH memory.

In the realized project, primarily the fingerprints of the persons to be authorized are read and stored in the flash memory on the fingerprint sensor. After that, When a person requests to go in SCR, he/she reads his/her fingerprint via fingerprint sensor. If the read fingerprint matches one of the stored fingerprints, relay will be active and the door of SCR will be opened. If scanned fingerprint does not match the registered fingerprints three times, buzzer will run and red LED will be ON. Once the alarm is active, it can be reset by logging in by someone with the correct fingerprint.

Finger print reading and control circuit diagram is shown in Figure 5.4.

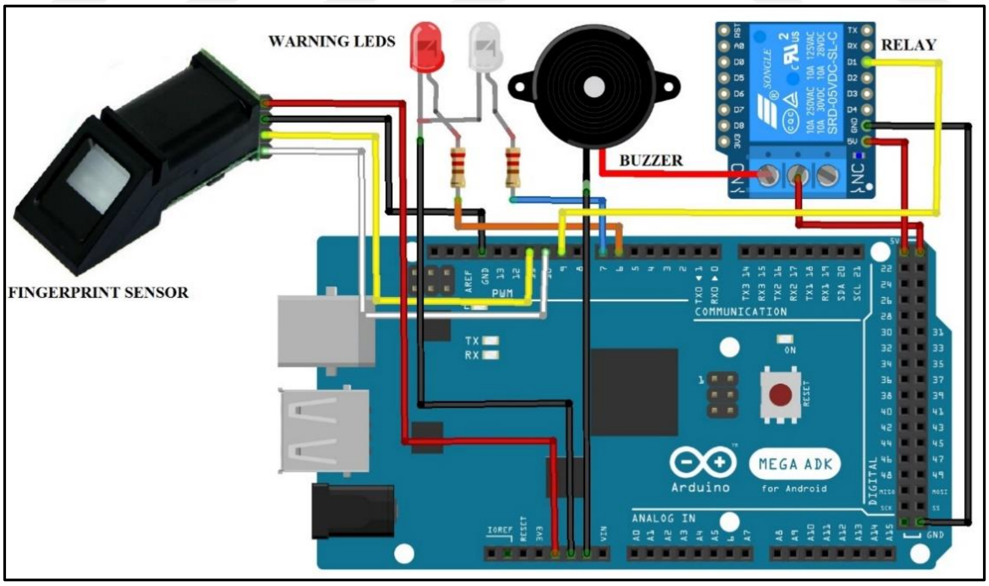


Figure 5.4. The circuit of fingerprint reading and control circuit

In the designed circuit, because cards used outside the MCU can be easily plugged to the MCU, the shield has been developed by using a printed circuit in Figure 5.5. The picture of realized project is given in Figure 5.6.

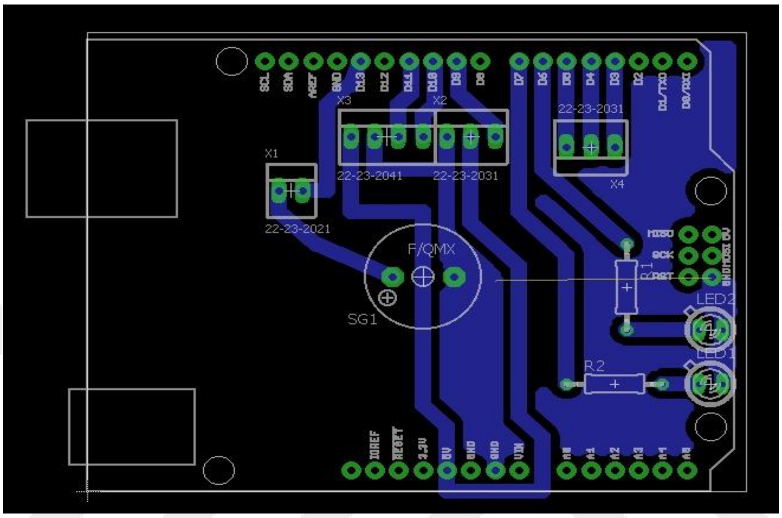


Figure 5.5. The printed wiring board of realized project

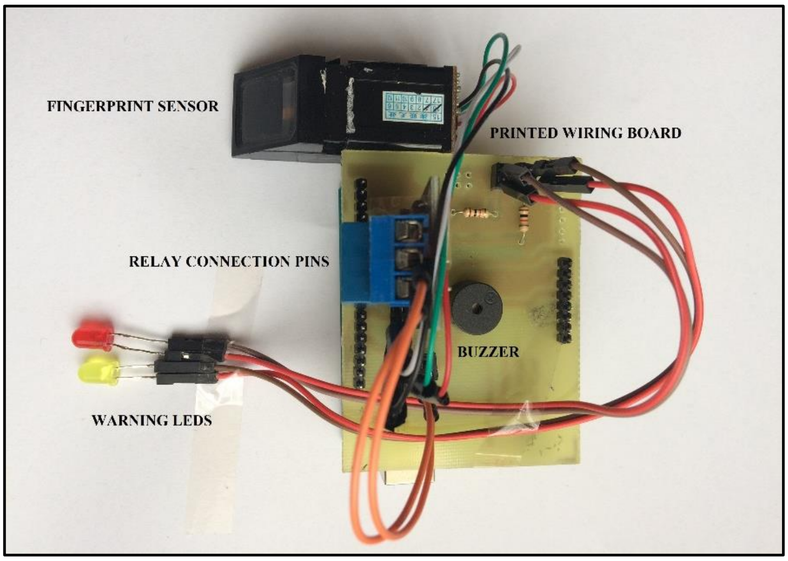


Figure 5.6. The picture of realized fingerprint reading and control circuit

The algorithm flowchart of door security system with fingerprint sensor is shown in Figure 5.7 in full detail.

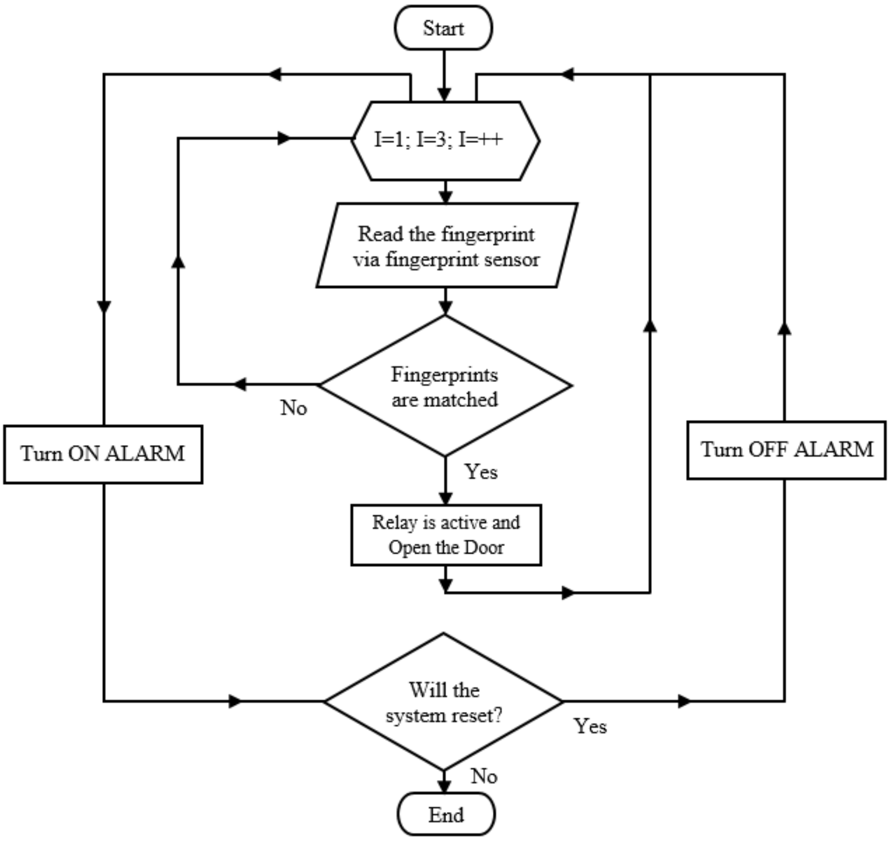


Figure 5.7. The flowchart of door security system with fingerprint sensor

5.3. Implementation of IP Camera

In this section, in the case of unauthorized access, the authorized staff need to monitor the room from remote to see what is going on. In this study, an android application to monitor the room from remote is developed.

Firstly, the access method to IP Camera must be selected. There are two different methods to remote connection of IP Camera. One of them is using of static IP and the other is using of dynamic DNS. One can easily access from outside to a local network which have a Static IP Address. Static IP addresses are assigned to a host by the network administrator (In Turkey, by Turk Telekom). Turk Telekom demands extra charges for assigning Static Ip Address.

In the case of Dynamic IP address, IP address of the user changes frequently. This is a problem if the user wants to provide a service to other users on Internet. As the IP address changes frequently, the corresponding domain names must be quickly re-mapped in the Domain Name Server, to maintain accesibility using a known URL.

In the realized project, free application which is called free dynamic DNS from downloading Internet was used. The service provides us a host name which is linked to our dynamic IP Address. Whenever the Ip changes the program sends an update to No-IP with the current IP address and No-IP propagates the DNS change to the Internet within seconds.

Thanks to this free application, All of virtual IP are routed the same real IP. Thus, when the virtual IP is changed, taken new IP will be routed the real IP automatically. Dynamic DNS application sample is shown in Figure 5.8.

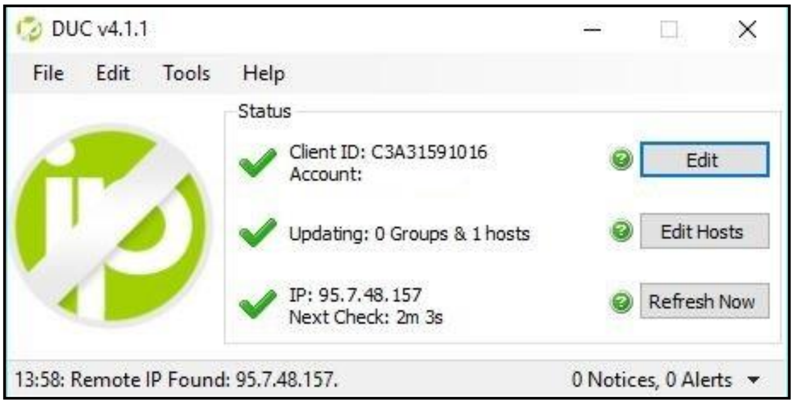


Figure 5.8. Free Dynamic DNS software

Android Application is built by using MIT App Inventor to monitor the IP camera from an Android device. When the user clicks the button, the program directs the user to an URL which is directed to the user interface of IP Camera. The user interface of android application is shown at Figure 5.9.

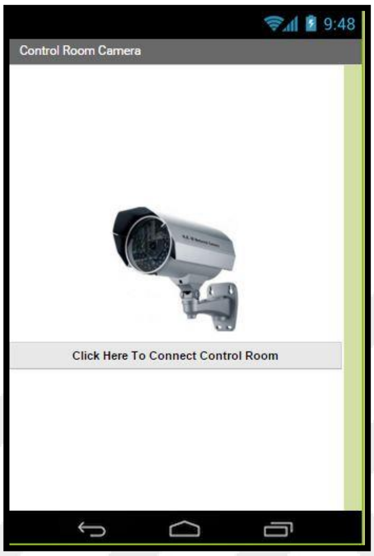


Figure 5.9. User interface of Android application

In addition, function blocks of Android application written by using MIT App Inventor is shown at Figure 5.10.

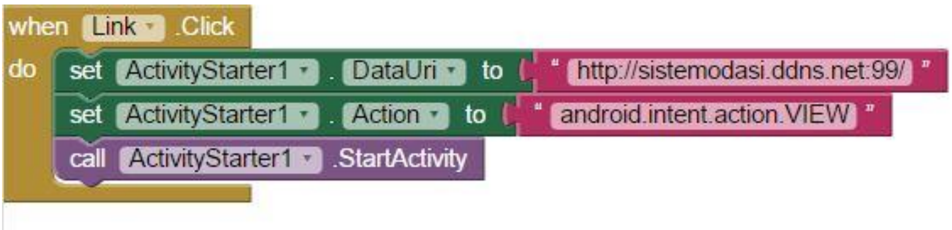


Figure 5.10. The function blocks of Android application

Finally in the realized project, Door Security System with Keypad, Door Securtiy System with Fingerprint Sensor and Alive Monitorizing of SCR with IP camera are combined as SCR Door Security System and the algorithm flowchart of new system is given in Figure 5.11.

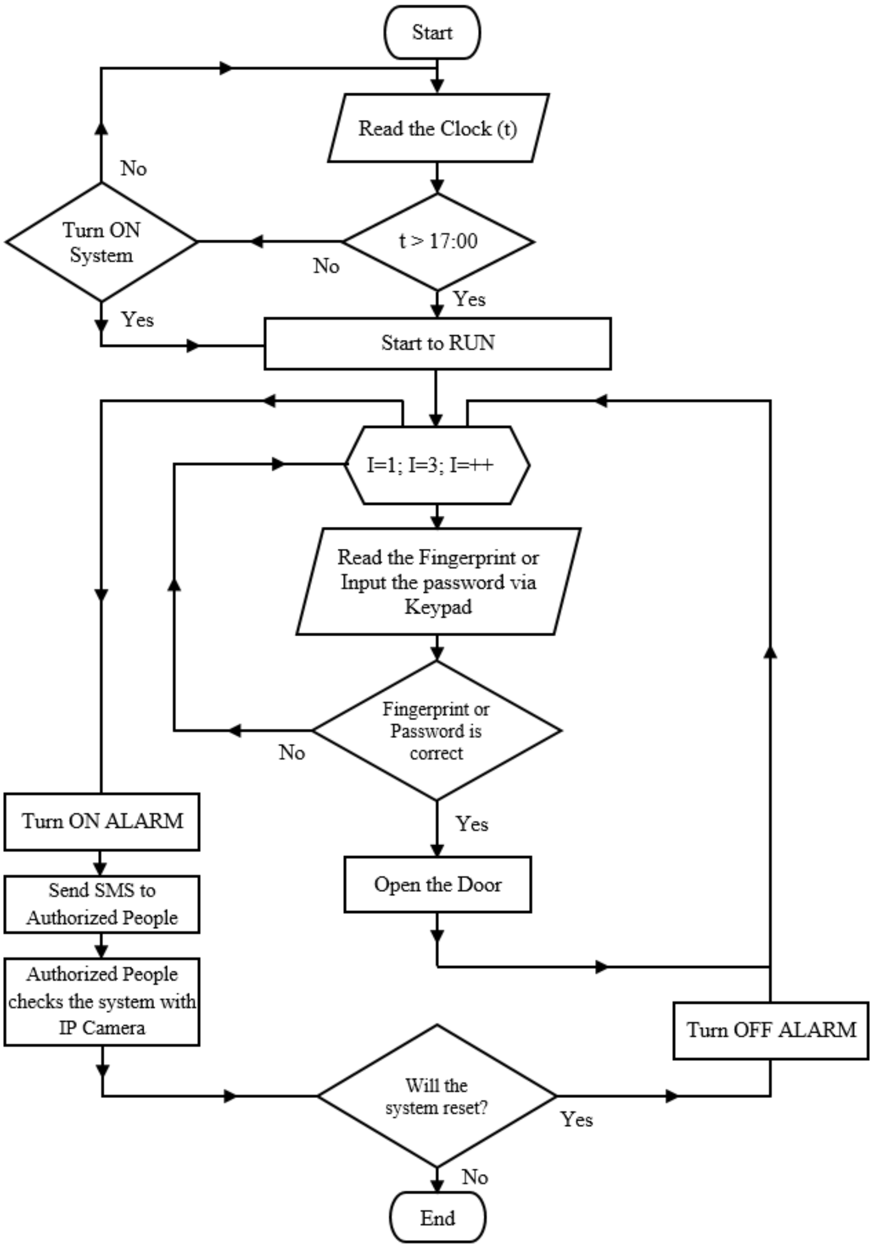


Figure 5.11. The algorithm flowcharts of SCR door security system

6. DESIGN AND IMPLEMENTATION OF FDCS

In this chapter, fire detection and warning system were developed. This section consists of four main steps. In the realized project, primarily, the detection of fire is needed. After the detection of the fire, the picture of fire should be taken by serial camera. Before the sending of Multimedia Message Service (MMS), taken picture should be saved in SD card. Subsequently, taken photo should be sent as MMS to authorized people. The authorized person receiving the picture message must be able to request a picture message again or activate the fire extinguishing system with android phone.

In order to realize the system, camera module, temperature sensor, flame sensor, gas sensor, SD card module on Ethernet shield, Arduino GSM/GPRS shield, and the original Arduino Mega card are needed. Technical features related to be used all devices are given in Appendix A. The used devices and sensors in realized project in this section has been explained at the next paragraphs.

6.1. Fire Detection Sensors in the Realized Project

In the realized project, flame sensor, gas sensor, and temperature sensor are used together. Flame sensors are used for short range fire detection. They can detect to presence of a flame or a fire. When they sense the flame or fire, analogue or digital output can be taken from the flame sensor. In the realized project, it is important that only the presence of fire exists or is absent. Because of this, digital output pin of the flame sensor was used.

Another sensor for using fire detection is MQ-2 gas sensor. The MQ-2 gas sensor has been converted into a module card by Seeed Studio. The MQ series of gas sensors use a small heater inside with an electro-chemical sensor. These sensors are sensitive for a range of gasses and are used indoors at room temperature. This sensor can detect H_2, LPG, CH_4, CO, Alcohol, Smoke, and Propane gases. When the sensor module detects the one of these type gases, this module gives analogue output. This analog signal is used by connecting to the analog input of the arduino card. If the reading value exceeds a certain value, one of the digital outputs of the Arduino is activated and the alarm relay is activated.

In the realized project, used other sensor is DS18B20 temperature sensor so as to fire detection. This sensor is the latest DS18B20. It can be used as thermostats. Morever it can be used for measuring of room temperature and smart home system projects. It doesn’t require external power supply. It can be powered from data line and power supply voltage range is from 3.0V to 5.5V. It can measure from -55°C to +125°C.

Whenever any of these sensors are active, carried out system has been run automatically.

6.2. Implementation of Serial Camera and SD Card on Ethernet Shield

Transistor-transistor logic (TTL) type serial camera is used for taking a photo in the realized projec. After the taking photo, it is saved to SD card and is sent as MMS to the phone. Monitoring distance of this camera is 10 meters and it can be adjustable up to 15 meters. Image size is maximum 640 x 480 pixels at VGA format and JPEG file.

When the one or a few of sensors are active, TTL serial camera will take a photo and save it in SD card on Ethernet shield. Subsequently, thanks to GSM/GPRS module, this picture files will send as a MMS message to a mobile phone. After the incoming message, authorized person connects to the system again and shoots a new photo or activate the warning and fire extinguished system by the software that works on the Android system. Thanks to this system, it has been aimed to reduce the fire risks.

Another hardware component is SD Card module to save data in it. The Arduino SD Card on Ethernet Shield is a simple solution for transferring data The communication between the microcontroller and the SD card uses SPI communication protocol, which takes place on digital pins 11, 12, and 13 (on most Arduino boards) or 50, 51, and 52 (Arduino Mega).

6.3. Sending of Multimedia Message by using Arduino

GSM/GPRS module are installed into the Arduino board to send a MMS. This card is compatible with Arduino Uno and upper cards. It can use both UART and software serial interface. It supports 850/900/1800/1900 Mhz Quad Band and it is suitable for GSM 07.07&07.05 and Enhanced SIMCOM AT Commands.

At the using GSM/GPRS module with AT commands has some important issues. One of them is to use capital letters for AT commands and the other is to send CR (Carriage return) and LF (Line Feed) after the AT command. In Addition, the serial communication jumpers must be right position. It can be needed to use external power supply. If the shield is powered from the Arduino, the power jumper must be in Arduino 5V position.

For the basic configuration of this shield, it must be connected to Arduino gateway and then connected the USB and the SIM (Subscriber Identity Module) card. After the basic configuration, Baudrate value must be selected 115200 bps and serial port must be opened for the connection of GSM card.

After that, it must be pressed the ON button for two seconds. Then if the OK message is came back from AT commands, this means that the communication with the module is working fine.

After the investigation of the devices, physical installation was carried out. The combining of the whole devices has shown in Figure 6.1. The connection pins shown in the figure are identical to the actual connections.

The working principle of the system can be summarized again briefly. Flame sensor, MQ-2 gas sensor, and temperature sensor are used to detect fire in this section. When these sensors are active, system will be run automatically. When the one or a few of sensors are active, Transistor-transistor Logic (TTL) serial camera will take a photo and save it in SD card on Ethernet shield. After that, taken photo will send to authorized people. If the authorized person requests to control to SCR, he/she can request to take a new photo and new MMS or he/she can activate the fire extinguishing system.

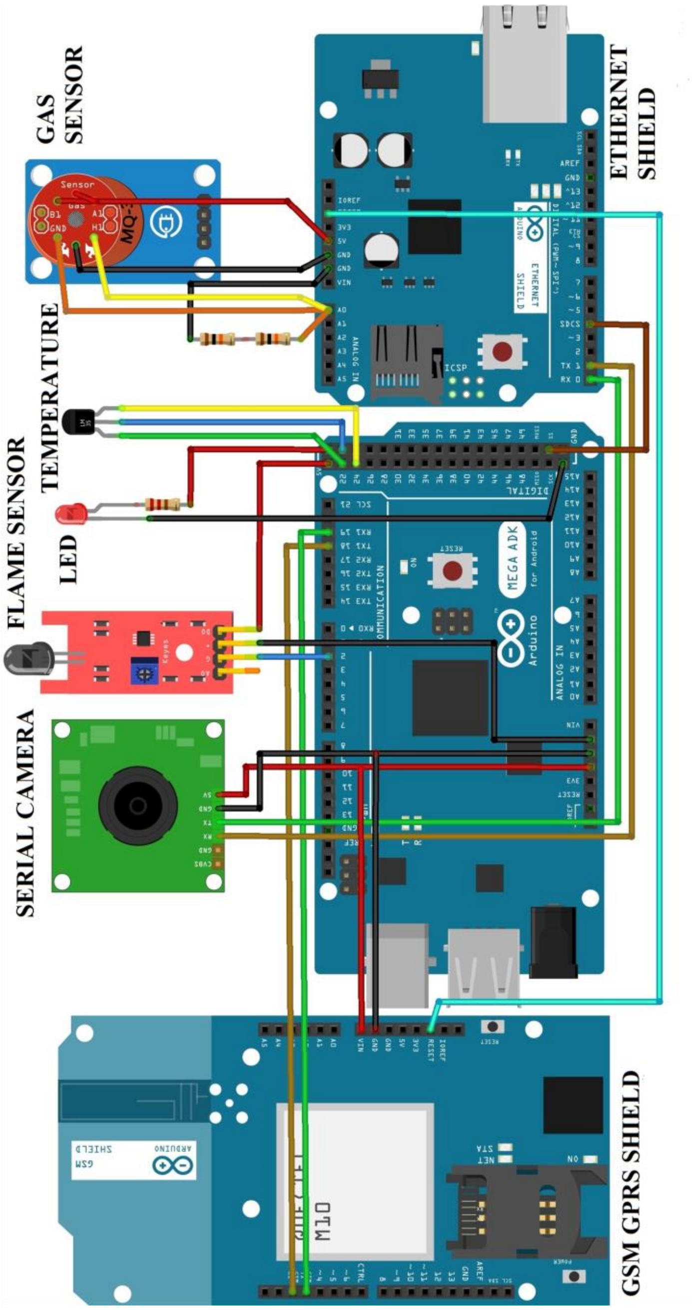


Figure 6.1. Circuit diagram of fire detection control system

Finally, the algorithm flowchart of fire detection control system is shown in Figure 6.2 in full detail

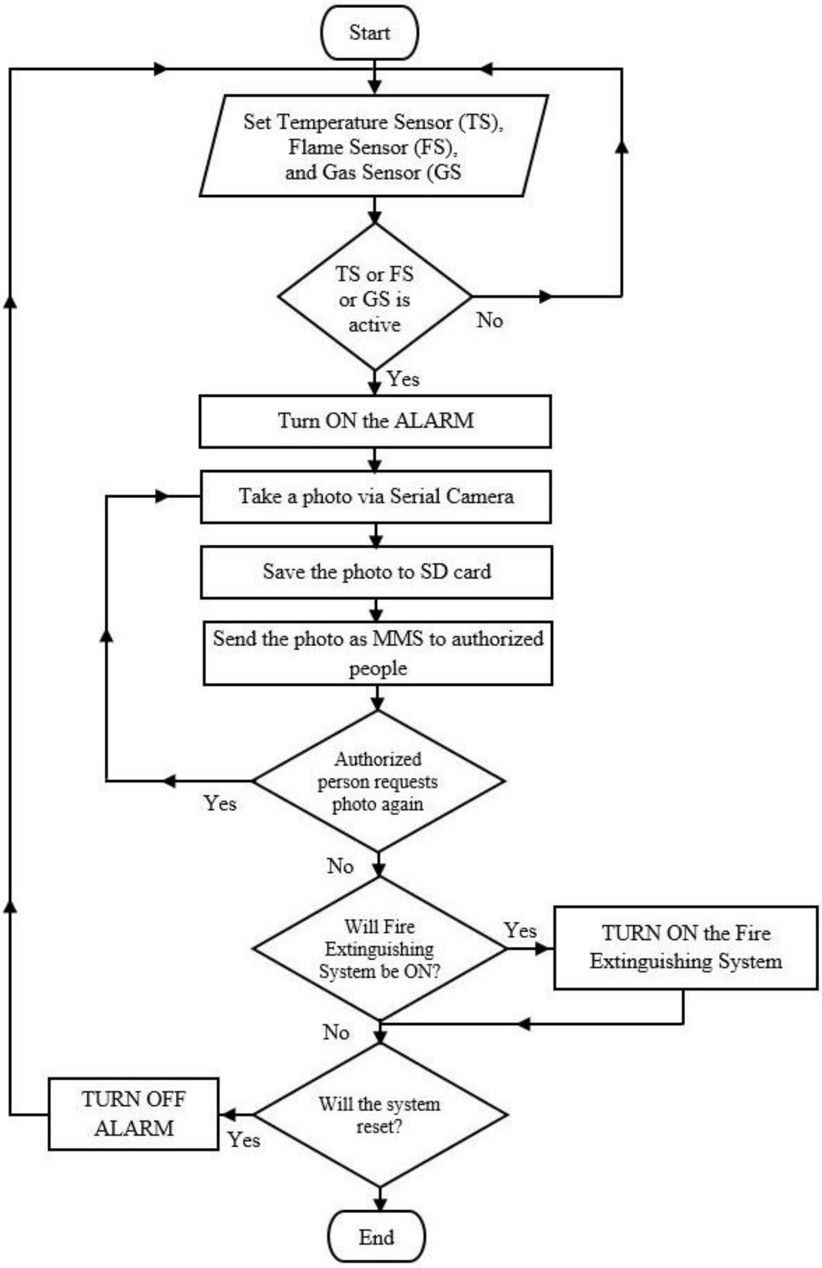


Figure 6.2. The algorithm flowchart of fire detection control system

7. AI TECHNIQUES FOR IOT LOAD FORECASTING

7.1. Introduction

Forecasting is an integral part of any sphere of human activity and energetics is not an exception (Filatova et al., 2015). With the recent integration of smart grid systems to today's power systems and the increasing penetration of renewable energy sources, the process for meticulous IoT load forecasting becomes more complex, calling for more effective techniques (Shen et al., 2016).

Moreover, due to nonlinear and nonstationary features of electric loads, which are affected by seasonal effects, weather conditions, socioeconomic dynamics, and random effects, electric load signals are characterized by high unpredictability, making the electric load forecasting a very arduous challenge (Cecati et al., 2015).

With respect to the time period, there are four categories of IoT load forecasting: (1) long-term, among 3-year and 50- year electric load is predicted, (2) if the forecast ranges from 2 weeks to 3-year, then it is considered as medium-term electric load forecasting, (3) short-term electric load forecasting (or short-term load forecasting, generally abbreviated as STLF in the literature) refers to hour, day or week ahead predictions, and (4) very short-term electric load forecasting which includes few minutes to an hour ahead forecasting of electric loads (Hong and Fan, 2016; Dedinec et al., 2016; Hong, 2010). In Figure 7.1 (Zor et al., 2017), applications of the forecasts according to forecasting categories are illustrated.

In this chapter, a state-of-the-art review of emerging and challenging two AI techniques for VSTLF is comprehensively presented. The paper is organized as follows: the last trends related to ANN and SVM are respectively described in the followings. Moreover, a comparison table is given under discussions and results. Consequently, a summary of the chapter is stated in the conclusions.

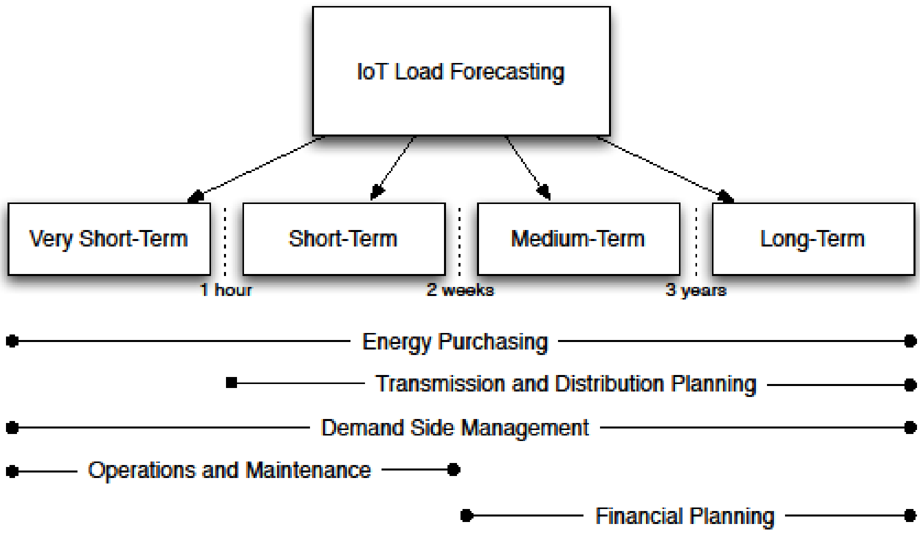


Figure 7.1. IoT load forecasting applications and classification.

7.2. Machine Learning Techniques

According to privatization and deregulation of power system, accurate electric load forecasting by using IoT devices has come into prominence recently. The new energy market and the smart grid paradigm ask for both better demand side management policies and for more reliable forecasts from single end-users, up to system scale. However, it is complex to predict the electric demand owing to the influencing factors such as climate factors, social activities, and seasonal factors. The methods developed for IoT load forecasting are broadly analyzed in two categories, namely analytical techniques and machine learning techniques. In the literature, commonly used analytical methods are linear regression method, Box-Jenkins method, and nonparametric regression method. The analytical methods work well under normal daily circumstances, but they can't give contenting results while dealing with meteorological, sociological or economical changes, hence they are not updated depending on time. Therefore, machine learning techniques have gained importance in reducing estimation errors. Artificial neural network and support vector machine are among these machine learning techniques. In the following paragraphs, two artificial intelligence techniques for short-term electric load forecasting is comprehensively presented.

7.2.1. Artificial Neural Network

The first mechanistic interpretation of the neuron doctrine was firstly credited by McCulloch and Pitts in 1943, Frank Rosenblatt actualized mathematical analysis, digital computer simulation, and experiments with special purpose parallel analog systems that neural networks with variable weight connections could be trained to classify spatial patterns into pre-specified categories (Nagy, 1991). Nearly 50 years after Rosenblatt's approach, different kinds of ANNs are very trendy as AI techniques, especially for electric load forecasting.

ANNs are intelligent systems that are successfully used to solve complicated problems in many different applications such as pattern recognition, identification, classification, speech, vision and control systems (Hasni et al., 2012). Neurons are the basic structural unit of nervous system and receive inputs from other sources, combine them in some way, perform a generally nonlinear operation on the result, and then output the final result (Kung, 1998). ANN can manage complex behaviors by the connections between the processing neurons and weight parameters (Yasin et al., 2015). ANN models fundamentally comprises of multiple connected neurons and nodes. The neurons have five basic components namely input, weight-bias, threshold, summing junction and output as illustrated in Figure 7.2. Neurons are being arranged as three layers which consist of input layer, hidden layer and output layer (Celik et al., 2016).

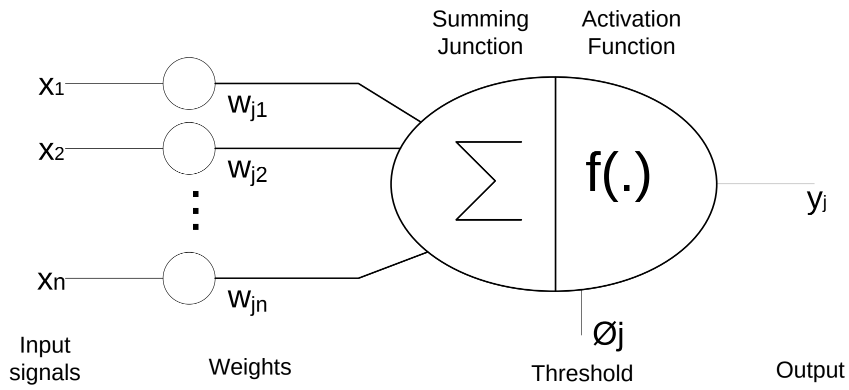


Figure 7.2. Basic structure of a simple artificial neuron

In Figure 7.3, one hidden layer multilayer perceptrons (MLPs) are demonstrated. MLPs are nonlinear functions to approximate a sufficiently regular function to an arbitrary degree of accuracy (Ding et al., 2016).

It is known that ANNs with excessive numbers of neurons and weights are easy to train. Besides, this may cause overtraining (Wilamovski, 2009). In addition to those, the power of ANN strengthens depending on its depth, but owing to vanishing gradient problem, the training gets very difficult (Hochreiter, 1998). To prevent from these problems, shallow ANN topologies with only one hidden layer are generally used as indicated in Figure 7.3 (Zor et al., 2017).

Lately, conventional feed-forward MLP ANNs have been replaced by radial basis function (RBF) networks (Yu et al., 2014; Huang et al., 2006; Xie et al., 2011; Hou and Han, 2010). In comparison with traditional sigmoidal ANNs, the RBF networks have minimal interaction between RBF units, because each RBF unit is frequently affected by smaller portions of input patterns.

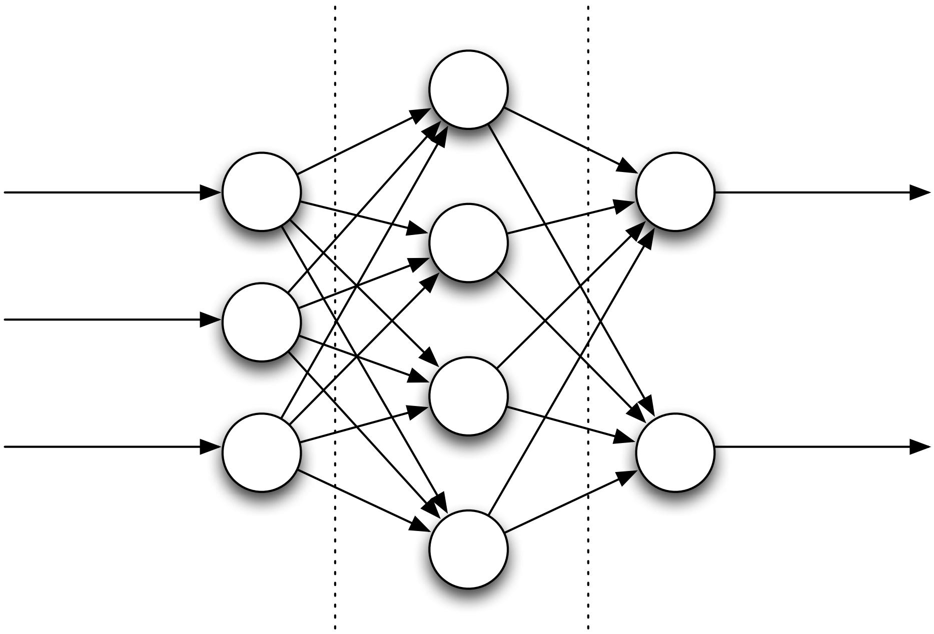


Figure 7.3. A basic feed-forward ANN topology with only one hidden layer

Mostly, RBF networks utilize solely one output. The hidden layer is constituted of the RBF units. Consider an RBF network with I inputs, H hidden units, and one output. Each unit in the hidden layer, h, executes a nonlinear operation expressed by the sequent activation function:

$$\varphi_h(\mathbf{x}_p) = \exp\left(-\frac{\left\|\mathbf{y}_{p,h} - \mathbf{c}_h\right\|^2}{\sigma_h^2}\right) \quad (7.1)$$

where $\mathbf{c}_h$ is the vector stating the center location of the RBF unit, and σ_h is the radius of the RBF unit.

In practice, instead of radii σ_h gamma parameter γ_h is used,

$$\gamma_h = \frac{1}{\sigma_h^2} \tag{7.2}$$

and (7.1) is transformed into (7.3),

$$\varphi_h(\mathbf{x}_p) = \exp(-\gamma_h ||\mathbf{y}_{p,h} - \mathbf{c}_h||^2) \tag{7.3}$$

The output signal for pattern p is calculated as the weighted sum of the outputs from the RBF units, and that is,

$$o_p = \sum_{h=1}^{H} w_h \, , \varphi_h(\mathbf{x}_p) + w_0 \tag{7.4}$$

In the RBF network with features stated above, there are several parameters that should be set:

- Weights of inputs $u_{i,h}$, (i=1, 2,…, I and h=0, 1, 2,…, H);
- Gamma parameter γ_h, (h=0, 1, 2,…, H);
- Locations of RBF centers $c_{i,h}$, (i=1, 2,…, I and h=0, 1, 2,…, H);
- Output weights w_h, (h=0, 1, 2,…, H).

Summary table for advantages and disadvantages of ANN as an AI technique is demonstrated below in Table 7.1 (Jalalkamali et al., 2015).

Table 7.1. Advantages and disadvantages of ANN

AI Technique	Advantages	Disadvantages
ANN	• Needs less formal statistical training • Has the capability of implicitly detecting complex relationships between dependent and independent variables • Has the capability of detecting all possible interactions between predictor variables • Has access to multiple training algorithms	• Its nature of being a black box • Has greater computational cost • Tends to overfitting • The empirical nature of model development

7.2.2. Support Vector Machine

SVM models have a lot of similarities with standard type multilayer perceptron neural networks. SVM can be utilized as an alternative in order to train classifiers containing RBF, polynomial and multilayer perceptron by using a kernel function. In the kernel function, solving a quadratic programming problem, which is related with linear constraints instead of dealing with a nonconvex and unconstrained minimization problem with training the ordinary neural network, determines the weights of the network (Ramli et al., 2015).

A training set $\Gamma = \{x_i, y_i\}_{i=1}^{n}$ is given where $x_i \in \mathbb{R}^d$ and $y_i \in \mathbb{R}$, the purpose of support vector regression (SVR) is to accomplish a forecast with good forecasting performance on forthcoming unknown instances (Che and Wang,2014). When dataset Γ is linearly independent, SVR solves problem as follows (Vapnik, 1995).

$$\min_{\omega,b,\xi,\xi^*} \frac{1}{2}\omega^T\omega + C\sum_{i=1}^{n}(\xi_i + \xi_i^*) \quad (7.5)$$

$$s.t.\begin{cases} y_i - (\omega^T x_i + b) \leq \mathcal{E} + \xi_i \\ (\omega^T x_i + b) - y_i \leq \mathcal{E} + \xi_i^*, \\ \xi_i, \xi_i^* \geq 0 \end{cases} \tag{7.6}$$

where Ɛ corresponds to the maximum value of tolerable error, ξ_i and ξ_i^* is the interval between actual values and the corresponding boundary values of Ɛ-tube, the trade-off of generalization ability and training error is decided by $C > 0$. Utilizing of the Karush–Kuhn–Tucker's (KKT) circumstances can solve the mentioned problem (Scholkopf and Smola, 2004). Then, the classic SVR would be the following linear regression function

$$f(x) = \omega^T x + b \tag{7.7}$$

where *ω* corresponds to the weight vector; *b* corresponds to the bias.

SVR has been expanded to solve the problems containing nonlinear regression with a linear method in a suitable feature space by using kernel trick (Taylor and Cristianini, 2004). Therefore, the sort of kernel function and the adjustments of kernel parameters decide the performance of SVR.

The below four sorts of kernel function named as linear, tanh, polynomial, and Gaussian kernels, are widely used in the literature. The linear kernel is

$$K(x, z) = x^T z, \tag{7.8}$$

the tanh kernel is

$$K(x, z) = \tanh(g x^T z + c), \tag{7.9}$$

the polynomial kernel is

$$K(x,z) = (x^t z + c)^d, \tag{7.10}$$

and the Gaussian kernel is

$$K(x,z) = \exp\left(\frac{-(x-z)^2}{2 \times \delta^2}\right), \tag{7.11}$$

where *g* is the slope of the tanh kernel (positive scalar), *c* is the off-set of polynomial and tanh kernel (scalar, negative for tanh), *d* is the degree of the polynomial kernel (positive scalar), δ is the width of Gauss kernel (positive scalar).

Summary table for advantages and disadvantages of SVM as an AI technique is demonstrated below in Table 7.2 (Jalalkamali et al., 2015).

Table 7.2. Advantages and disadvantages of SVM

AI Technique	Advantages	Disadvantages
SVM	• By the regularization parameter, user can avoid overfitting • Expert knowledge about the problem can be built by kernel trick • Defined by a convex optimization problem (no local minima) and there are efficient methods to solve it	• The first and biggest limitation depends on the choice of kernel • The second limitation in speed and size for both in training and testing stages • Significantly slow in the testing stage

Commonly, SVM models are implemented in MATLAB by LIBSVM which is an integrated software for support vector classification and regression (Chang and Lin, 2016).

7.2.3. Case Study

An accurate knowledge on power consumption of control room is essential for promoting energy efficiency and sustainable operating of basic services. Therefore, it is one of the inevitable necessities to accurately estimate consumption based on changing atmospheric conditions. Several linear, non-linear and soft computing models are available to estimate the power consumption. However, it is crucial to choose the most appropriate model for a specific purpose. In this study, feed-forward MLP model with Scaled Conjugate Gradient algorithm, RBF network, and SVM are utilized to extract the power consumption characteristics of the control room. Thanks to the presented model, it is possible to estimate the power consumption of the room and take precautions according to different chaos situations. Thus, the healthy operation of the devices will be provided in case of power failure, data loss will be prevented, and operating conditions will be provided permanently.

7.2.3.1. ANN based IoT Load Forecasting

In this study, ANN is utilized to forecast the electric loads of the control room by historical electric load data and the additional data obtained from the outdoor humidity and outdoor temperature in Adana for the averaging period of 10-minute as inputs.

Different back propagation algorithms are used to train the multilayer perceptron ANN. In the developed ANN model, supervised learning technique with multilayer feed forward network with SCG, learning algorithm and RBF network are utilized. A logistic sigmoid transfer-function and linear transfer function used in hidden layer and output layer, respectively. Three layers which include input layer, hidden layer and output layer are constituted in the model as illustrated in Figure 7.4. The accuracy of the model depends on the number of neurons in hidden layer, the number of hidden layer, input combinations and learning algorithm. MAPE is used to evaluate accuracy of the method. MATLAB software “Neural Network Toolbox” is employed to implement presented model.

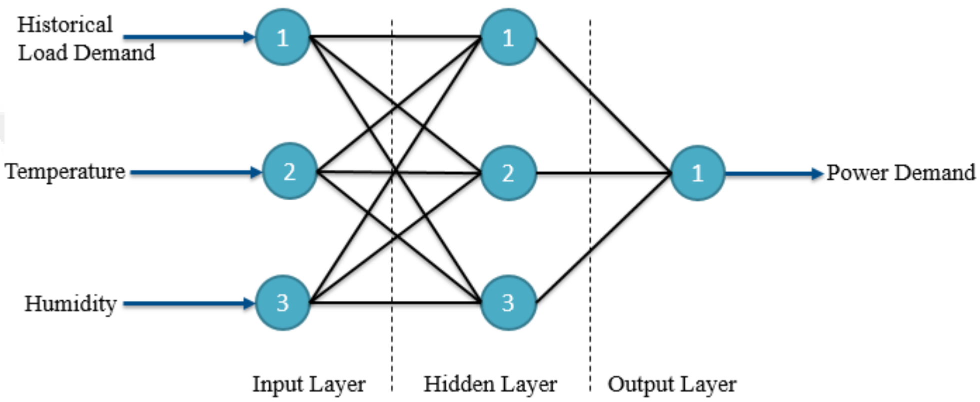


Figure 7.4. ANN model for prediction of power demand

7.2.3.2. Data Description and Parameter Election

In order to develop the ANN model, first of all the appropriate input variables are determined and secondly, number of hidden neurons are selected. These steps are employed with different learning algorithms and number of hidden layers. The input and target data should be adjusted in the range from 0 to 1 for normalization. Then, according to the statistical results of preliminary studies, relevant input parameters are selected. The ANN system is selected as 2x1008 input matrix with 1x1008 output matrix. This selection is based on the remarkable estimation results which obtained by evaluating different input configurations. The input/target dataset were divided randomly into three subsets: training; validation; and testing dataset. Numbers of hidden neurons are varied from 2 to 50. Some of the system parameters are given as; number of epoch is 10000, minimum gradient

1e-6, minimum improvement delta 1e-6, convergence tolerance 1e-5, 10-fold cross-validation is used for preventing over fitting, learning algorithms are Levenberg Marquardt and Scaled Conjugate Algorithm, hidden layer activation function is logistic and output activation function is linear. Due to the values of the weights are randomly assigned, the model was run about 50 times to obtain the best results.

7.2.3.3. Training and Testing Problem

80% of dataset is used for training, 10% of dataset is used for testing and 10% of dataset is used for validation. The network is implemented with different input combinations, hidden layer number and hidden neuron numbers for several times. The reason of several attempts, weights and biases are chosen randomly and this affects the accuracy of the model. On the other hand ‘over fitting’ is obstructed with the using of early stopping techniques. When the error on validation set increases for a defined number of iterations, the training process is finished automatically.

In this study, the system is trained by using SCG learning algorithm, forward feed multilayer sensor model, RBF and SVM methods and the amount of electricity consumption of system control room is determined as a result of statistical evaluation methods. As input data, outdoor temperature and humidity were recorded by reading with 10-minute intervals. According to these values, the amount of energy required for cooling in emergency situations will be estimated by teaching the amount of energy consumed by the air conditioner unit in the system room. As a result of the study, taking precautions against different situations that may occur, data loss will be prevented in case of any power interruption.

The accuracy of the model depends on the number of neurons in hidden layer, the number of hidden layer, input combinations and learning algorithm. MAPE is used to evaluate accuracy of the method. MATLAB software is employed to implement presented model. All results of ANN and SVM study are shown in Table 7.3. As can be seen in the table, the SVM method yields a more efficient result than the ANN method.

Table 7.3. The results of ANN and SVM

Model	Input Parameters	Learning Algorithm	Neuron in Hidden Layer	MAPE (%)	
				Training	Testing
ANN (MLP)	Historical Load Demand (HLD), Temperature, Humidity	SCG	11	8.04	8.35
			18	7.93	8.31
			25	7.92	8.33
			36	7.85	8.33
			42	7.80	8.37
ANN (RBF)	HLD, Temperature, Humidity			8.31	8.63
SVM	HLD, Temperature, Humidity			7.78	8.17

7.2.4. Results and Discussion

In order to compare the performances of two investigated AI techniques, mean absolute percentage error (MAPE) is employed as an error calculation method and it is given as

$$\mathrm{MAPE}(\%) = 100 \times \frac{\sum_{t=1}^{n} |(X_t - X'_t)/X_t|}{n} \tag{7.12}$$

where X_t is output values and X'_t is target values (Azadeh et al., 2013).

7.2.5. Summary

IoT load forecasting has gained importance with the recent integration of smart grid to electric power systems and the increasing penetration of renewable energy sources. However, it is complicated to predict future electric loads accurately due to the influencing factors such as climate factors, social activities, and seasonal factors.

There are two commonly utilized techniques in order to forecast electric loads and they are analytical and machine learning techniques. Analytical methods operate well under normal daily conditions, but they can not adapt the changes, because they are not updated depending on time. Therefore, these make AI techniques popular and suitable especially for STLF.

In this chapter, the fundamentals of two machine learning techniques for VSTLF, which are ANN and SVM are described in details. Analysis showed that two different machine learning techniques have the potential for excellent forecasting.

8. DESIGN AND IMPLEMENTATION OF SOFTWARE CODES

Software codes of the realized project consist of two main parts named as server and client sides. The server software runs on a Windows based server environment and it is the main framework of the whole software. All client software applications use data of database which runs on the server. Similarly, client software can also run on Windows based server. In addition to old traditional Windows application, Web and Android based applications are developed in order to access the realized project from anywhere. The flowchart of the designed project is shown in Figure 8.1. Besides, general features of all software platforms are given as follows,

- Developed server software is used to communicate between the server computer and ZigBee coordinator. ZigBee coordinator device is like a bridge between the server and the router/end node devices. Data coming from all sensors are sent to server computer and data coming from the server computer is sent to all router/end node devices via the coordinator node device. All devices can be communicated bidirectionally.
- Data coming from sensors are saved to the database tables and saved data should be controlled periodically.
- Data coming from sensors and controller circuits are analysed and monitored on the screen. If it is requested, data in the database severs can be analyzed and can be monitored by the table and graphical charts.
- A detailed report is prepared for measured values and the energy consumption, with graphical charts and tables. Users can check energy consumption of any device by using client software.
- According to the determined critical values, running systems can be controlled automatically. What is more, all SBMS can be controlled remotely by using the web interface or Android devices.

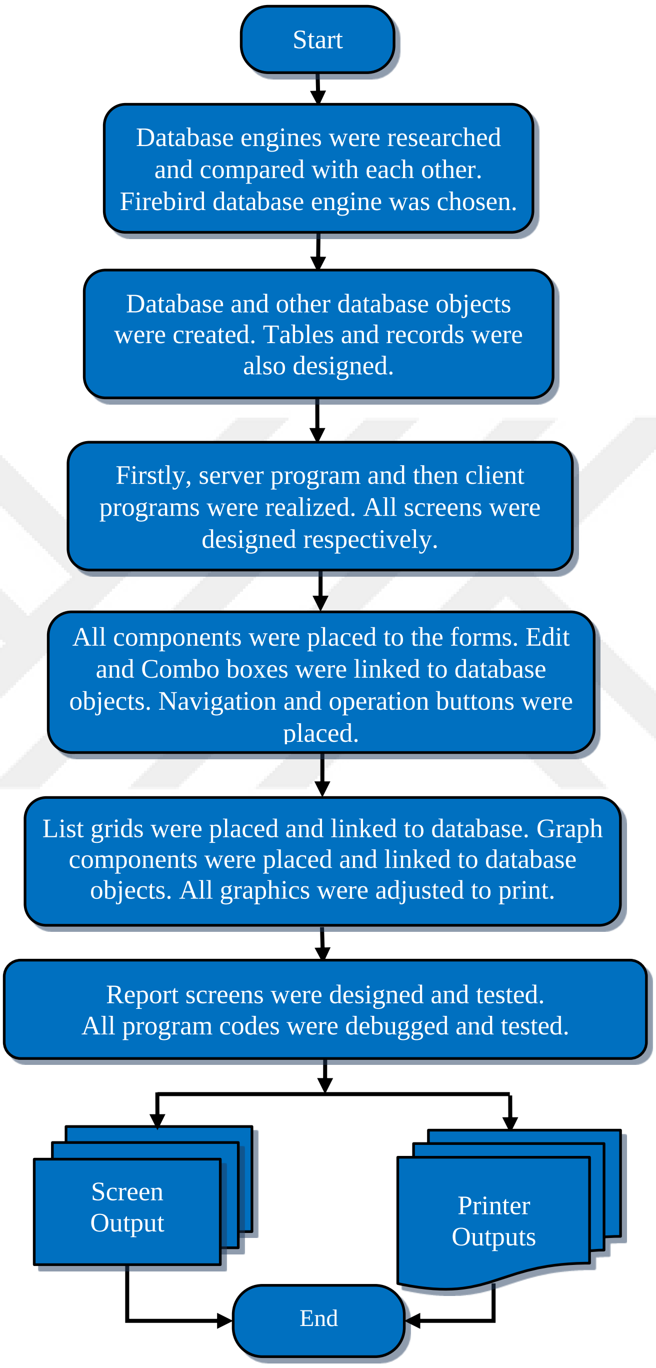


Figure 8.1. Flowchart of the developed software

8.1. Choosing the Right Software Application Development Environment

This software project is based on Server-Client architecture. Most known integrated development environments (IDEs) support this type of structures. Hereby, server operating system which server software runs on plays an important role. Server software can be operated under several operating systems. In this study, Windows Server environment was chosen because of management, easy installation, and wide technical documentation support and hardware compatibility. On the other hand, client applications should be performed under desktop, mobile, and Web browser environments. There is no development solution supported by all environments. When IDEs are investigated, it is determined that most of the development platforms only support desktop environments. Few of the others support at most two of these environments. RAD studio environment developed by Embercadero supports both desktop and android mobile platforms. It contains C++ and Delphi Builder at the same time. Delphi is based on Pascal programming language which was created by Borland Software Company. It has a very fast compiler and powerful debugger indeed. Because of mentioned features, Delphi IDE was preferred in this study.

By Delphi IDE, Windows, Linux and MacOS based applications on the server and desktop client sides, IOS and Android based applications on the mobile side can be developed. In addition, domestic, full performance, and platform specific client application can be developed for any platform. The most powerful specification of this IDE is to write one source code and to compile it different operating environments domestically. This development environment has a powerful text editor, but it also has a simple user friendly design environment. The environment has a lot of component repositories, debug operations which is integrated into a text editor. Moreover, it has a viewer for CPU registers and local variables and very fast compiler. This compiler can approximately operate 1 million lines in a minute. Embercadero Company has developed DATASNAP technology and integrated it into their development environments. This technology provides data moving methods between server and client as an object or objects specification. This technology runs with TCP/IP. So, its connection capability has near limitless because of the Internet. In order to improve the performance of the developed application, the data requests made by the client are converted into the procedure and function on the server side and run on the server, and the obtained data are sent in plain text format. With this method, applications gain performance and simplicity. If it is desired, these data can be subjected to filtering operations such as encryption and compression.

Application development language supports Object Oriented Programming approach to reduce development time and improve code quality. Furthermore, the debugger of IDE can debug the source code locally or remotely. Because of superior properties of Delphi with the integrated development environment, Delphi compiler is preferred for this study.

Primarily, server software is written and then desktop client software is developed sequentially. The developed software is written by Delphi XE 10.2 developer version which can develop excellent applications running on 32-bit and 64-bit Windows desktop environment. After the desktop application, Android mobile software is designed by using components developed for Android applications. If it is requested, Android source codes can be used for MacOS applications without any changes. Finally, Thinfinity VirtualUI software of Cybele Software is used for converting the desktop application into a Web application.

Code development features of Delphi XE 10.2 is powerful. Delphi is allowed to connect to widely known databases such as Oracle, PostgreSQL, Interbase/Firebird, MySQL, Microsoft SQL server, SQLite and so forth.

8.2. Choosing a Database Engine

Most of the computer software need a database to save data. The realized software also needs a database to save measured sensor values such as current and voltage. Similarly, calculated values, report data, and the all other data should be stored in the database too. Because of storing big data, data processing speed of database should be very fast. What is more, it should be portable and should be taken place in less disk size. The selected database should be run on Windows, Linux and MacOS operating systems and it should be both installable and portable. It should be run either on 32-bit or on 64-bit operating systems. When the huge amount of data are demanded in the future, it should meet these demands by scalable feature.

Most of the enterprise class databases meet these requirements but they are very expensive products and not portable. Embedded databases are portable, fast and easy manageable products. Additionally, they use less disk size and they don’t need any installation. Some embedded databases are open source and they are free.

When the embedded databases are compared to each other, it is determined that some databases don’t support Structure Query Language (SQL). Thanks to SQL, all data in a database can be analyzed, filtered, and manageable. When the huge amount of data are processed, application processing speed is the most important factor. Since SQL is developed for big data, it is fast and efficient. Because of this, a database in the realized project has to support SQL.

Firebird is an open source, fast, portable, and scalable. Furthermore, it supports SQL. It can be run on different platforms such as Windows, Linux, MacOS, and Solaris. Data produced by Firebird can be transferred from the one platform to another. There are three main versions of Firebird. First of them is Super Server version built for Windows environment. Second is Super Classic version developed for multi-user. It can be run on a different operating system such as Windows and Linux. Third of Firebird version is the embedded version which is portable, small and power full database engine. In the realized project, the required features are completely met by Firebird Embedded Database Engine.

8.3. User Interface Design

In the realized project, the user interface was designed with page logic. Most people have used Microsoft Office applications. Generally, Excel applications have one main window and a lot of tabs. The design of these tabs provides facility to manage a lot of different page at the same time. This design has increased the usability and accessibility. Everything is as far as a mouse click. Delphi has a form design appearance manager which is based on the objective. The views of the application can be chosen and changed by using the appearance manager.

8.4. Miscellaneous Programs

Some miscellaneous programs were used at the development stage. One of them is IBExpert software. IBExpert is a software used to create a database. It is used for maintenance and management of Firebird database engine. Database objects can be created such as a database, table, index, view, etc. At the same time, database object properties can be changed by using IBExpert. The maintenance of the database is executed by this program. Briefly, the proposed project has required creating and managing of the database structure on the disk.

Unidac is a component of Delphi. It is provided most known database engine connection components. Every database object has logical components in Delphi environments.

Quick Report is a report builder component in Delphi. One can create very detailed reports automatically from the database table. Reports can be previewed on the screen, printed to a printer or saved to disk by using this component.

Teechart is a graphic drawing component in Delphi. By this component, stored data in the database can be directly drawn graphically. Graphic types, series colors and etc. can be chosen. Drawing graph can be previewed, printed or saved.

In this project, database design is prepared after determining the development environment, database engine, and other development tools.

8.5. Database Design Basics

Database design procedure has two stages: One of them is logical database design and the other is physical database design.

In the logical database, design stage is decided by which variables are represented and which database areas are used. Simultaneously, variable types and sizes are decided. This stage can be named as Decide Process. In the physical stage, logical objects are created. This stage can be also named as Realize Process.

In the realized project, database object SmartControl.FDB was created. The database file has five database tables. One of them is DEVICE table. It stores the information of the devices. The second table is SENSORS table. It stores the sensor information of devices. The third table is SENSORLOGS table. It stores the sensor values periodically. The fourth table is VALUES table. It saves the measured values by calculating the program based on the sensor table data. The last table is a MEM_VALUE table. It saves the different sensor log values by reading periodically for creating reports and graphs. Firstly, main database file SmartControl.FDB was created by IBExbert program as shown in Figure 8.2.

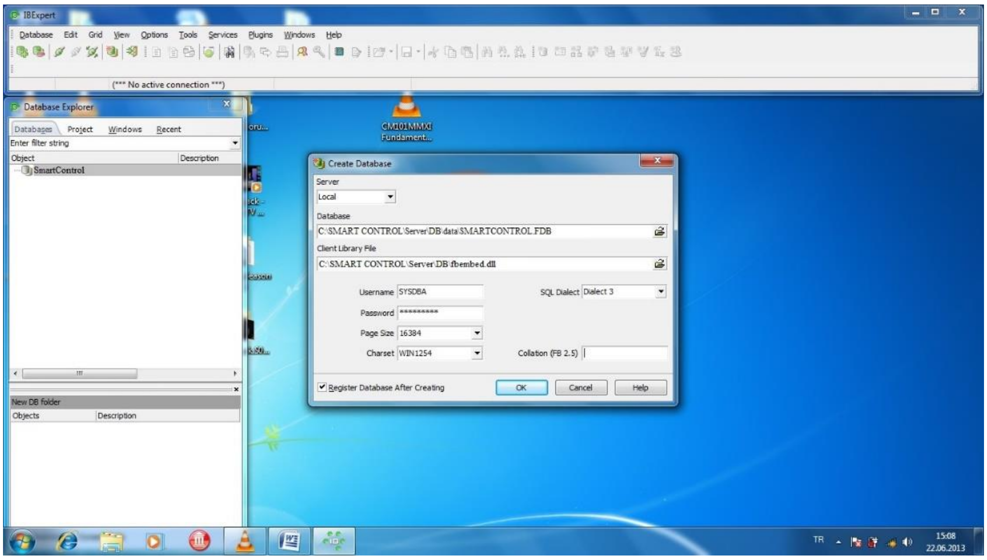


Figure 8.2. Database creation stage with IBExbert tool

After this process, the creations of database tables and other database objects such as domains, index, and so forth were started to design. Column name, size, type and other parameters in the table were defined and created as shown in Figure 8.3. In the table, for quick access to data, indexing should be used. There can only be one primary key in a table. However, the primary key of another table can be connected to the other table as a foreign key. Thus, two tables will be related to each other.

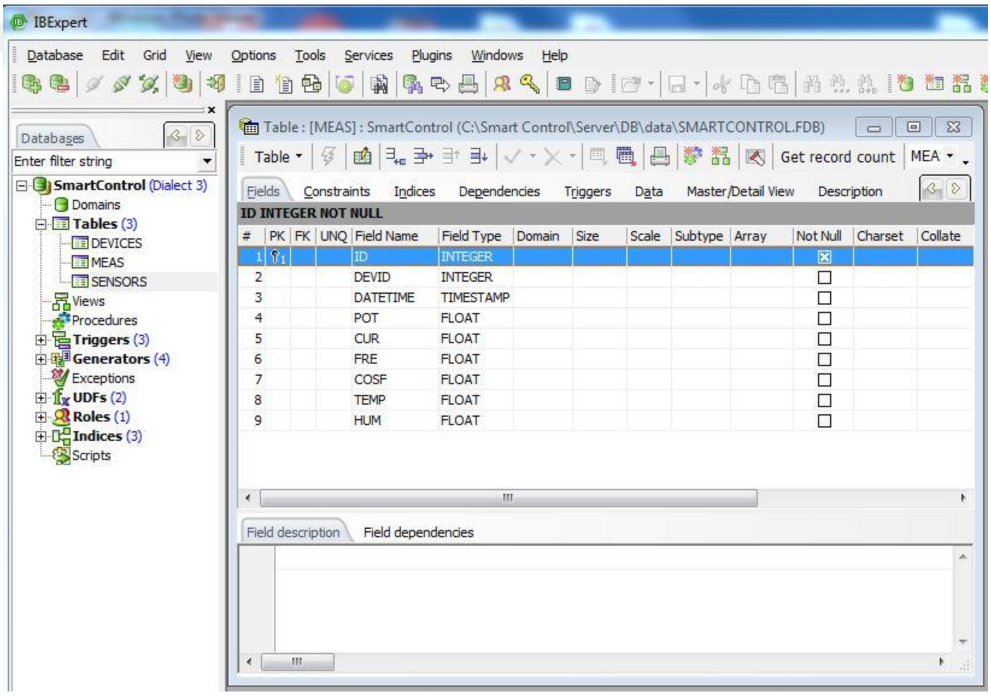


Figure 8.3. Table creation stage

After the all database table creation, application screen should be designed and program source codes should be written. In Figure 8.4, Embarcadero RAD Studio XE 10.2 has been used for the designing of user screen and writing of the source codes. During the opening of the Delphi IDE, whether licence is active or not and all components added to the Delphi IDE later are displayed on the screen.

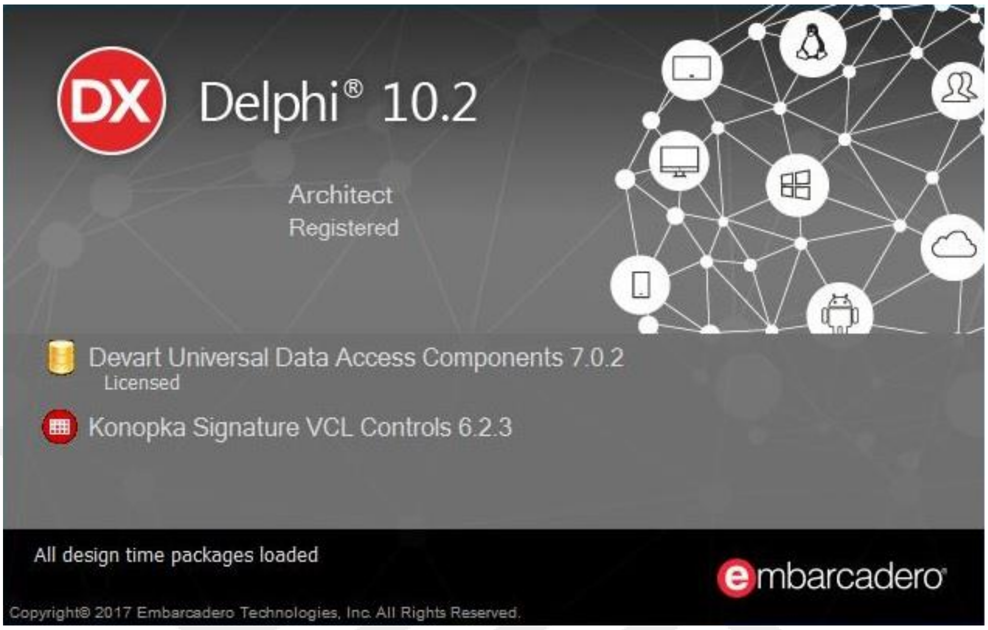


Figure 8.4. Delphi integrated development environment (IDE)

This study was developed on the Delphi IDE. Delphi IDE has a code editor to write program code, a project manager to manage the project files, a component pallet to store the Visual Component Library, an object inspector to see and change the object properties and assign the code block the object events, and of course an integrated debugger to find and debug the logical or structural program bugs. In Figure 8.5, Delphi IDE with its all components is shown together. As shown in the figure, there are three main tabs on the welcome screen. In the Start Here screen, a new code page can be created or old file written by Delphi can be opened. In the Tutorials and Documentation Screens, there are a lot of educational documents, videos and other sources. In addition, the help library of Delphi and more information via Internet can also be accessed by using these two screens.

In Delphi development environment, processed data in the database tables can be seen and run practically. It is a very useful and important feature. It is an easy way to design and test the designed program.

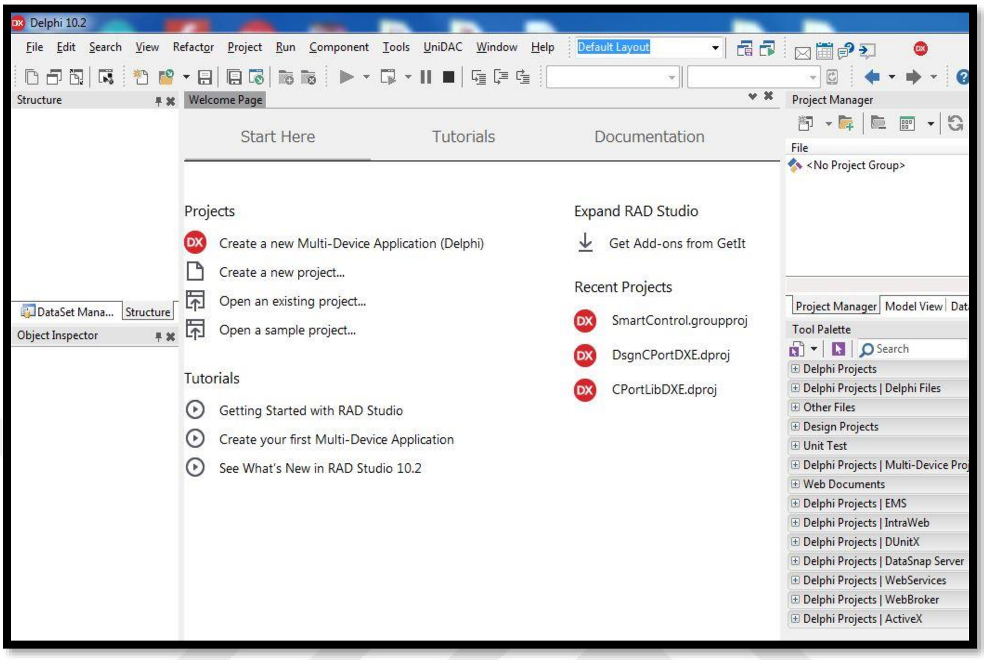


Figure 8.5. Delphi development environment

Primarily, startup screen was designed for application as shown in Figure 8.6. This screen is a login screen. This screen has header a section, login section, and status bar section. In the header screen, the program name is given as Smart Building Management System. In the login section, user name and password should be known in order to enter the application. While the authorized people are determined, a unique username and password are given each person and this information is stored in the database as a password table. If the username and password are matched, the entering of the program will succeed. Otherwise, the user cannot enter into the program. Finally, in the status bar section, some information related to the program is given. Especially, whether the connection of COM port is or not and whether the right password is known or not and so forth can be displayed in this section. In addition, date and time values of the status are saved to the logging table in the database. Thus, realized status can be traced to step by step if desired.

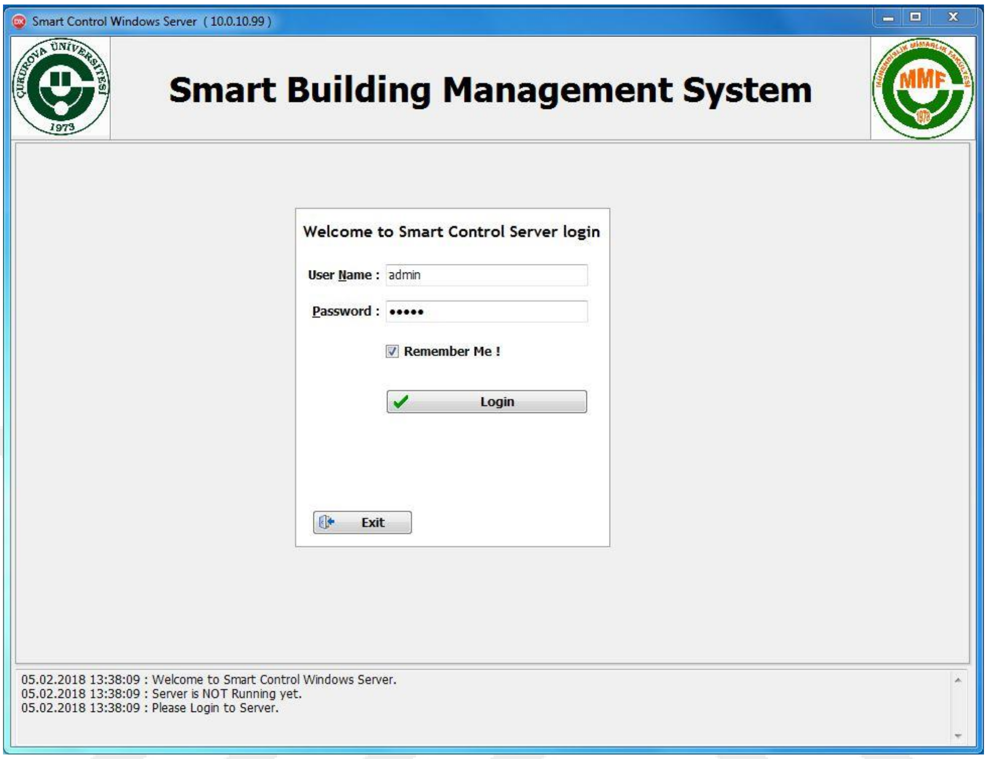


Figure 8.6. Welcome screen of the proposed program

After this stage, database form which holds the all database object was designed. This form has a database component named as SmartControl.FDB which represents physical database file on the disk. Every database table is represented by four database components.

The first component is a table component that represents the physical database table in the database file.

The second is a transaction component that is responsible for management every read or write operation to the table object. This component is used to write the data which is entered or changed the physical disk file or rollback the operation.

The third component is an update component that is responsible for storing the SQL sentences for every operation such as Insert, Update, Cancel, Delete, Save, and Refresh operations. When the user clicks the button on the form to start or finish the database operation such as starting of data entry, editing of the record, deleting of the record, and so forth. Table components take the SQL sentences from this component and add some parameters and send it to the database engine for processing.

The fourth component is data source component that is responsible for linking the table component and every other database enabled components. It works as a bridge between the components and table objects.

All components related to database objects are shown in Figure 8.7. This screen is also named as appearance screen. The background picture can be added via this screen. Moreover, default views can be selected by using appearance list box. Selected view or added picture will be shown on every screen in the program.

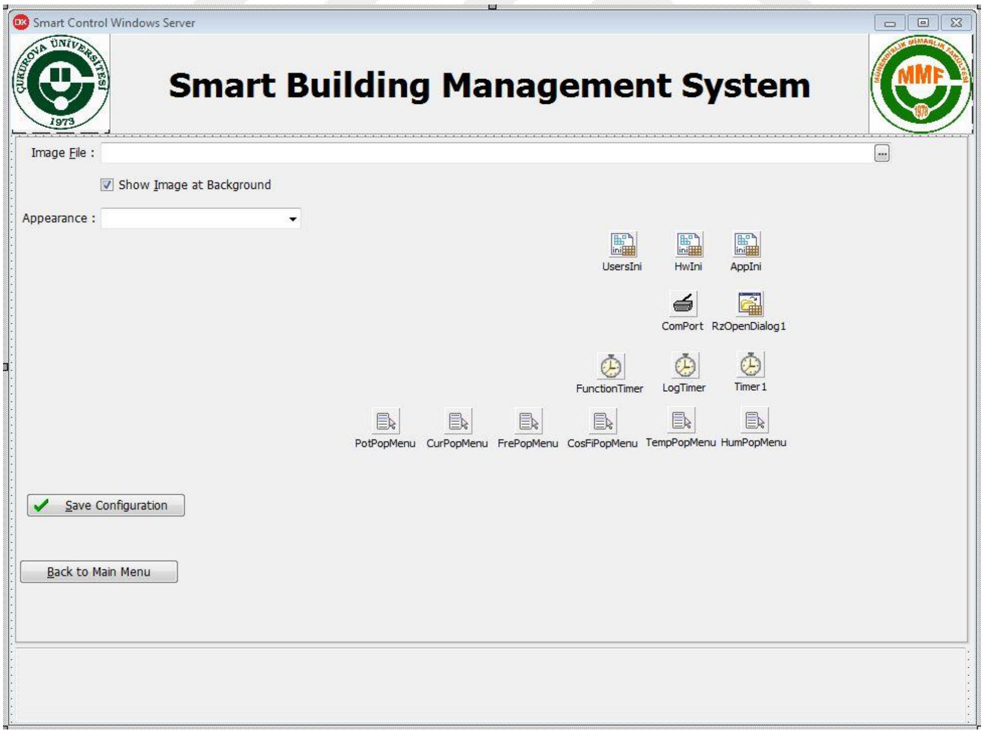


Figure 8.7. Database objects screen

After this stage, main screen, sensor values reading screen, log screen, report screen and the other screens were designed. Value reading screen is shown in Figure 8.8 exemplarily. In this screen, reading values from the sensors are shown in graphically. These graphics can be zoomed in by double clicking of the mouse from the small form to full screen and can be printed out if desired.

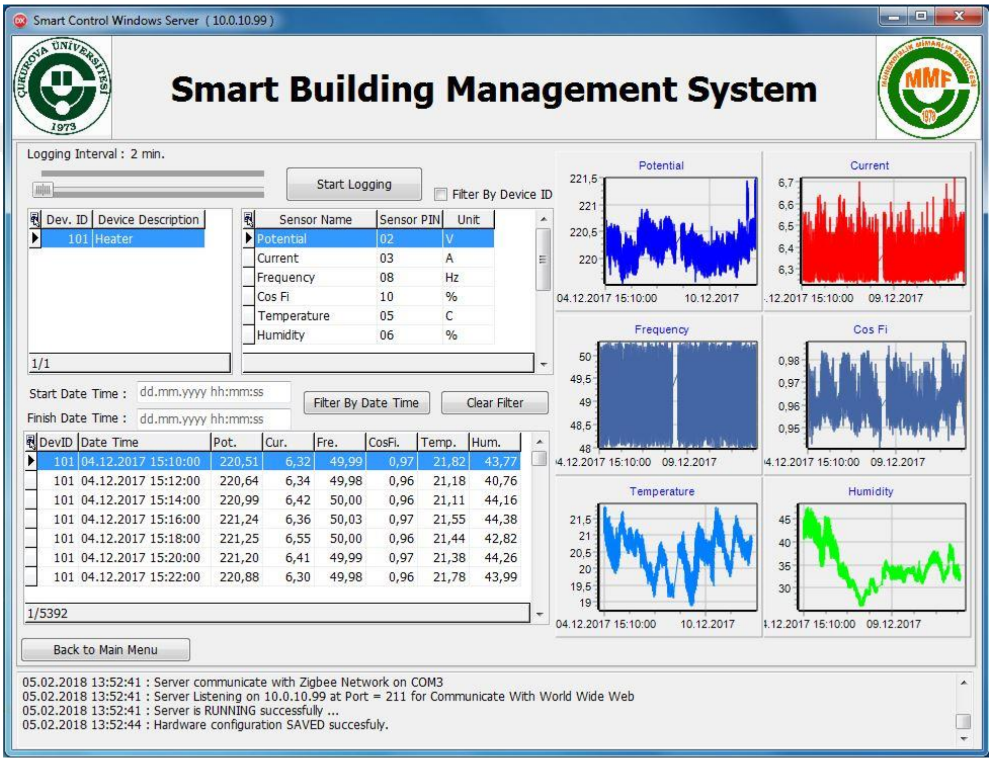


Figure 8.8. Sensor values reading screen

The realized project screen has four tabs. The first tab is the main screen. In this tab, the screen has four areas. The first section is Hardware Configuration section. The second section is appearance setting area. The second section has the Windows program appearance settings. The appearance and color settings of the whole program can be changed. In the third area, the all basic functions of smart systems can be checked. The basic values can be monitored periodically. Forth area is the graphic area. In this area, the sensor values both in values in database and as a graph by day basis can be seen.

In the hardware configuration section, Zigbee devices and computer interface communicating settings can be adjusted. Additionally, maximum and minimum values of reading values from the sensors are determined as warning values. When the read values drop below or rise above the warning values, program will give warning. If it is desired, the system will be shut down automatically. In other words, with the help of this screen, serial port connection parameters and critical sensor values can be defined easily. Hardware configuration and warning limits adjustment screen are shown in Figure 8.9. In order to pass the previous screen, Back to Main Menu button should be used.

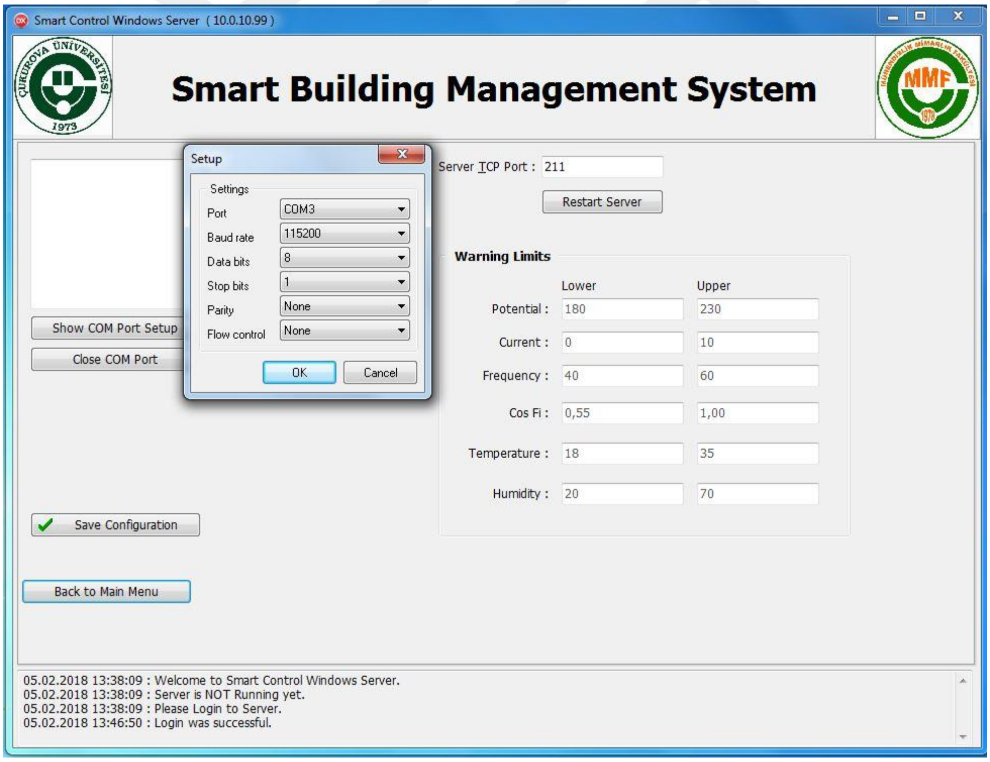


Figure 8.9. Hardware configuration and warning limits adjustment screen

The second tab is named as Functional Test. In this tab, the device number can be entered and then wanted pin number can be tested. Basic micro controller functions, analog and digital write and read functions can be also controlled. Additionally, the values returning after the executing the functions can be seen. The reading sensor values such as potential, current, efficiency and frequency can be checked as online. Every function can be read periodically and also individually. Period time can be set by the user. Every reading value can be read as a group of operations. Functional Test screen is shown in Figure 8.10. In this screen, all embedded cards can be tested before commissioning. Thus, the possibility of an error occurring will be minimized. At the same time, this screen is used for monitoring of reading values manually or automatically. For the automatic mode, interval time should be determined and Auto Update Check box should be selected.

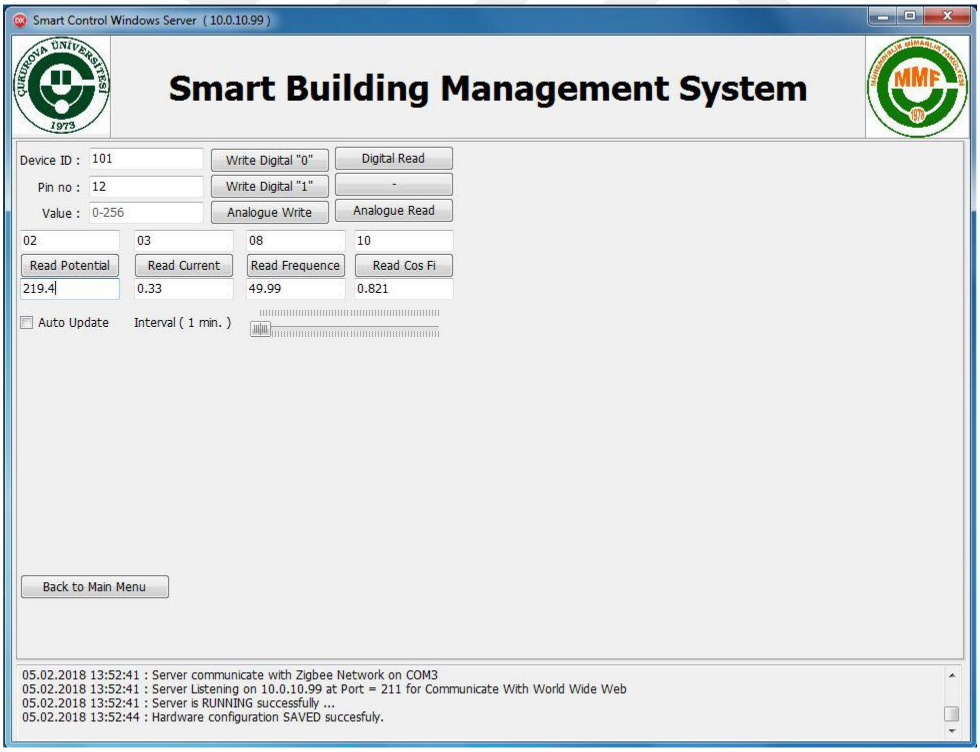


Figure 8.10.Functional test screen

The third tab is named as appearance set screen. In this screen, the background image can be set. Moreover, the appearance of the program selected from the list can be changed. Appearance settings screen is shown in Figure 8.11. Before leaving this screen, the changes made should be saved by using Save Configuration button. Otherwise, all changes made will be invalid.

Figure 8.11.Appearance settings screen

After the screen design and component linking stage are finished, program coding stage can be started. Delphi code editor for writing program is shown in Figure 8.12. There are all components, their properties, and their events menus in the code editor. With the help of all components, all screens such as logging screen, report screen and their all codes were realized easily.

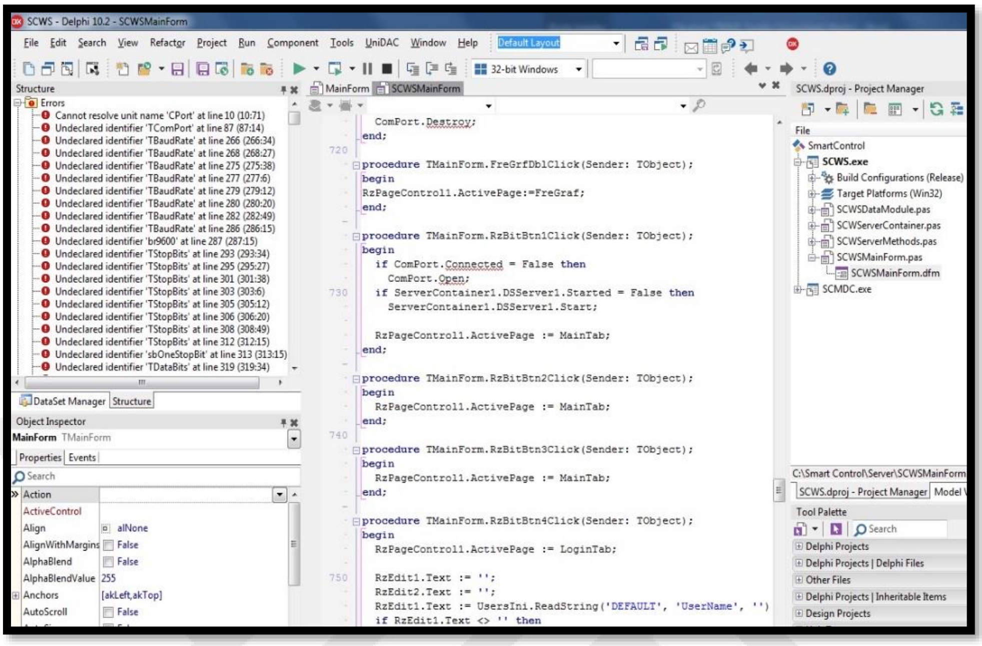


Figure 8.12.Delphi development environment: Code editor

Code editor has many important features. One of them is code compilation. Code editor underlines the wrong code when the code is written. In Delphi, development environment can add a breakpoint to wanted lines. The program debugger can be run. The program debugger traces all writing codes and the line which has a break point where compiler stops the operation and code editor shows the breakpoint lines or code writing errors. Delphi Debugger is shown in Figure 8.13. The code can be followed and examined variables' values. In addition, the codes can be changed by the variables' values and can be run by the program step by step and line by line. It is an easy way to find the wrong code or logical design errors. After the errors are detected, it must be corrected and then corrected codes should be compiled again. Finally, software without any errors should be converted into an application.

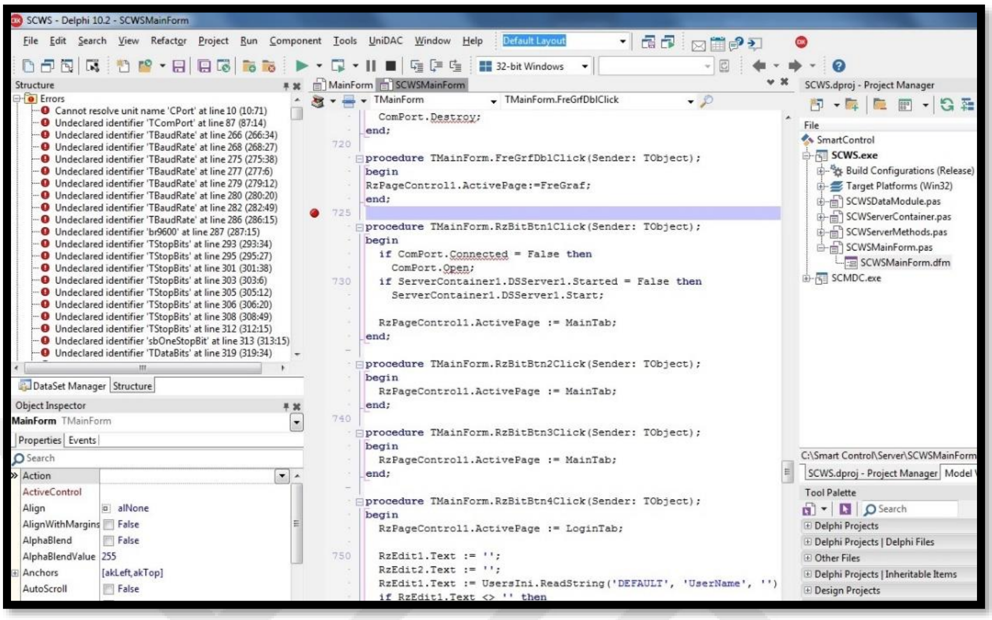


Figure 8.13.Delphi development environment: Just in time debugger

After the full form designed and the code is written, the realized project software was run without any problems. Thus, server application and the majority of the desktop client application were completed.

Android based mobile application is developed by Delphi code editor. Android based components are different from the desktop components. Because of this difference, new screen designs should be implemented for Android based software. According to mobile device sizes, design screen sizes can be selected. Android based software screen samples are shown in Figure 8.14. In this figure, three different screens are shown together. The first screen is the connection to the main server. In this screen, IP number of main server computer should be entered. In the second screen, main menus of the Android software are shown. The third screen is used for the reading data from all sensors. After the wanted coordinator or end node number is entered, it will be possible to get its own data.

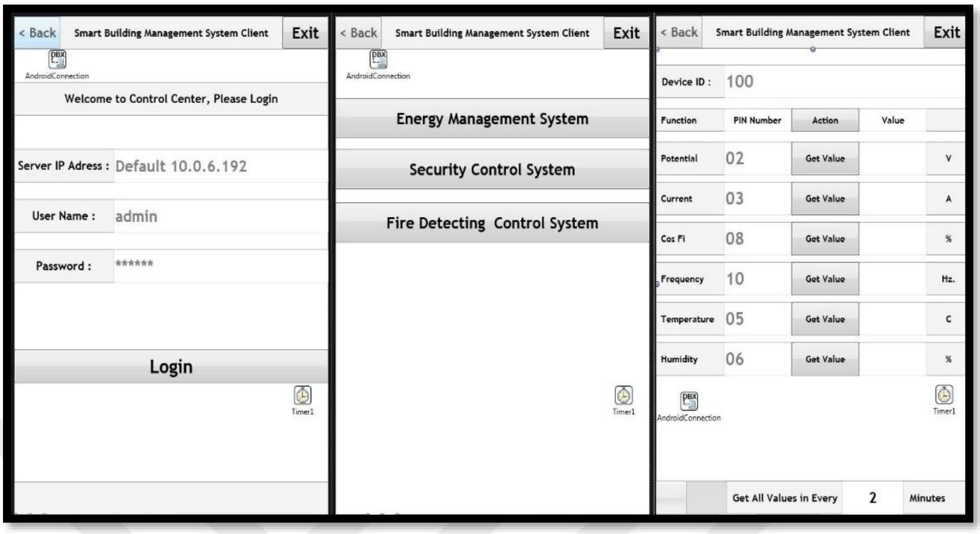


Figure 8.14.Realized Android based software screen samples

Finally, the application is turned into Web-based by Thinfinity VirtualUI software of Cybele Software after some small revisions as shown in Figure 8.15.

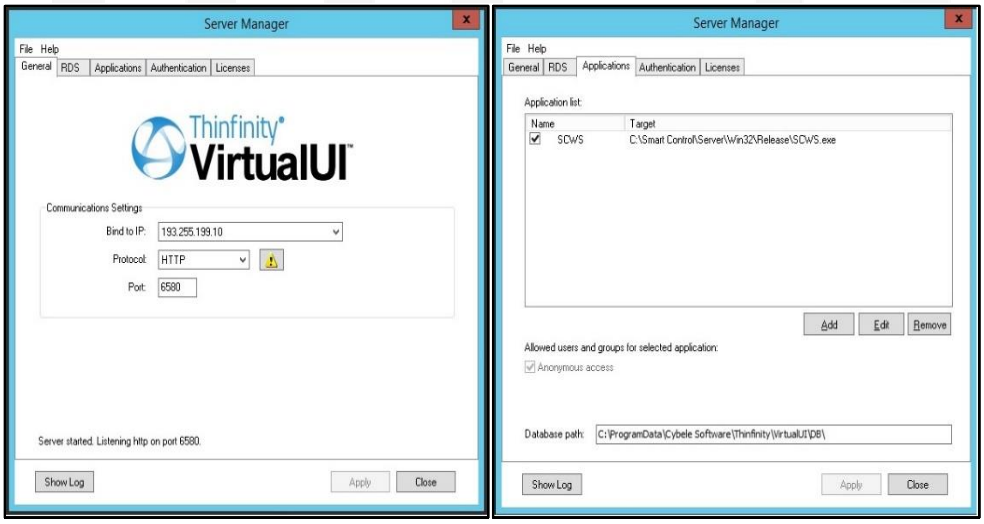


Figure 8.15.Thinfinity VirtualUI software screen samples

9. CONCLUSION AND FUTURE WORK

9.1. Conclusion of Thesis

Technological developments have caused changes and improvements in the needs of humankind. People could access to required information by using written sources within days in more recent times, they can currently reach to millions of data via search engines solely within seconds. The introduction of smartphones into our lives and their widespread development at a pace that pushes the boundaries of mankind's imagination has led to the advancement of other intelligent systems as well. Desktop and laptop personal computers have been superseded by tablets and mobile phones. Changing hardware requirements have also brought about changes in software needs. Programs executed by unportable computers and servers in LAN have been supplanted by web based or mobile applications that can be run independently from time and place.

Due to the increase in the number of devices connected to the Internet, the existing Internet protocol (IPs) named as IPv4 (IP version 4) seems to be inadequate against evolving technology. It is anticipated that the inadequacy of IPv4 will be solved by the arrival of IPv6 (IP version 6) whose addresses are 128 bits long. In 2003, there were approximately 6.3 billion people on Earth and 500 million devices were able to connect to the Internet. Division of the number of connected devices by the world population gives a result that there was less than one (0.08) device for every person. Today, IoT is on the cusp of exponential growth. Looking to the future, Cisco Internet Business Solutions Group (IBSG) predicts that by 2020, there will be 50 billion devices connected to the Internet and the world population will be around 7.6 billion which makes more than six (6.58) devices per person.

In the realized project, considering developments in smart systems and IoT objects, studies were carried out and the following results were obtained step by step.

In the introduction of this thesis, fundamentals of smart systems and control methods are summarized. Especially, studies related to smart buildings are investigated to present energy consumption amount, energy saving potential, and future energy consumption prediction of smart buildings. After a comprehensive survey of smart buildings, embedded cards frequently used in the literature are compared with respect to their capability to be procured easily. As a result of comparisons and evaluations, the embedded card with a brand and model named as Arduino Mega ADK is preferred as microcontroller before investigating communication protocols. ZigBee communication protocol is chosen among wireless communication protocols and is used for all embedded cards throughout the thesis.

In chapter 2, articles and conference papers of major publishers such as IEEE, IEE, and Elsevier related to the thesis have been firstly surveyed and comprehensively summarized in order to follow the recent advances in the literature. Herein, application studies are managed to prefer to simulation studies. Smart buildings and systems, embedded cards and Arduino, communication protocols and IoT are summarized as a consequence of detailed research.

In chapter 3, SBMS is introduced. SBMS contains input and output devices, embedded system cards, server, and user sections. When the previous studies are investigated, it is seen that separate software programs have been developed for each embedded card. In the scope of this thesis, all of the embedded cards are classified into two groups with respect to the purpose of use. As a consequence of the classification, a single software program code for each class has refined for standardization. If there is a need for adding new cards to the system later, one of the standardized code lines will be loaded and executed according to the intended use of the card. Standardized codes and load over an embedded card with a limited resource has been lightened by transferring to the server. The limited resources that embedded cards have are too small in comparison with the resources that advanced computers have. This study is the first of its kind in the literature when similar studies in the past are investigated.

In chapter 4, steps of EMS realization of SMBS is expressed. Firstly, SP's design and implementation is the backbone of EMS and in the scope of this thesis, SP is aimed to design in order to convert traditional devices into smart devices. By the developed SP, values such as current, voltage, temperature, humidity, cos φ, and frequency can be measured. The amount of consumed power and energy of the device has been calculated with respect to the values. Measurement results are compared to a more sensitive measuring device, and the maximum error is found as 2%. In addition to SP implementation, air-conditioner control system and LED dimming studies are carried out. As a consequence of these studies, a rough saving of 22% is obtained. In this chapter, STS is developed to supply power consumption of embedded cards and benefit from solar energy lastly. Thus, consumption of all embedded cards can be supplied without the need of a separate power source.

In chapter 5, SCS application is realized. If it is desired to enter the system room after the hour 17:00, entrance with a keypad or fingerprint control has been ensured. A login with three false keypad combination or three unidentified fingerprints in SMS database causes a termination of entry, an alarm activation, and sending a short message to authorized personnel. The personnel, who receives the short message, can monitor by using IP camera.

In chapter 6, FDCS application is fulfilled. In FDCS, when a high value is read on one of gas, flame, smoke, and temperature sensors, activation of alert and MMS has been provided. Authorized personnel can monitor the condition of the system room by checking MMS. MMS with a photo can be desired by authorized personnel again or IP camera mentioned in chapter 5 can be used for the alive view. Additionally, the personnel can remotely activate fire extinguishing system on request.

In chapter 7, data obtained from the SP are used to predict system room's future loads in order to keep the room temperature constant by using ANN and

SVM methodologies. The power demand for air conditioners, outdoor temperature, and outdoor relative humidity are employed as input parameters of very short-term forecast study. As a result of the forecasting study, MAPE values of MLP ANN and RBF-kernel SVM are calculated as 8.55 and 8.17 respectively.

In chapter 8, information related to programmed server and client-side software is given. Client-side software is based on Windows-based operating system and it is executed on Windows 2012 Server. FireBird database is chosen instead of SQL Server for being open source. Rather than using separate languages such as C#, ASP.NET and MIT App Inverter for user platforms, the Delphi compiler, which can be converted to an Android-based application by making minor changes in the desktop application, is chosen as the programming language. Therefore, users can manage devices at the remotest point in the system via three different graphical interfaces in order to access SBMS.

Developed SBMS has a flexible structure. Any device having analog or digital inputs can be included in the system by making small electronic modifications. It should be noted that input and output voltages of embedded card used as microcontroller are 5 V_{dc}.

The conducted study is expandable without depending on a specific brand. This project can be utilized in different buildings for diversified purposes. A part of the developed project is commissioned in the main system room at Balcalı Hospital. If the physical conditions are satisfied, the rest of the project will be commissioned in the main system room as well.

Consequently, in this thesis, the implementation of a wireless network for energy monitoring, analysis, and management in smart buildings is carried out.

9.2. Future Work of Thesis

For taking this thesis a step further, recommendations for future work are given as follows.

- If the developed SBMS is used for all electrical appliances and illumination systems in households, entire energy consumption of households can be examined in details. At the present time, smart electricity meters can only measure the overall energy consumption of households without classifying the loads. Unnecessary consumption of specific devices or appliances of households can be determined and controlled in order to prevent from energy wasting by the developed SBMS.
- If the devised system is not only used for households but also for the entire building, the amount of electrical energy consumption of the whole building will be obtained and recorded. Moreover, it will be a guide for companies dealing with demand-side management whether the developed system is applied to the overall neighborhood. In case of using methods in the buildings or the neighborhood such as load shifting, etc., energy saving is foreseen.
- ZigBee protocol is allowed to provide a communication speed up to 250 kbps, hence it cannot be used for the circumstances in which large data needs to be transferred. For transferring large data such as video screaming, a hybrid structure of ZigBee and XBee Wi-Fi module or Wi-Fi is suggested.
- Arduino Mega ADK, which is used as a microcontroller, has 10-bit analog-to-digital converter with a sensitivity of 5 mV. For a better sensitivity, the use of 16-bit analog-to-digital converter is recommended. As a result of this changing, sensitivity will be at the microvolts level.

- It is recommended that using one of Arduino Nano or Micro cards increases the compactness of the system, because of the fact that either one of them requires less space in comparison with Arduino Mega ADK card.

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CURRICULUM VITAE

Oğuzhan TİMUR was born in Adana, Turkey in 1974. He received his B.Sc. degree in Electrical and Electronics Engineering Department from Çukurova University in 2000. After completion his B.S. education, he worked as Electrical and Electronics Engineer in textile factories (Özbucak and BosSA) until 2008. He received his M.Sc. degree in Electrical and Electronics Engineering Department from Çukurova University, Adana, Turkey, in 2013.

He has been working as an Electrical and Electronics Engineer at Hospital Information and Management Systems Department of Çukurova University Balcalı Hospital since 2008. His research areas are power electronics, energy efficiency, energy management, renewable energy resources, embedded cards, Internet of things, smart buildings, smart grids and the other smart systems. In addition, he is interested in computer programming, computer network systems and servers.

APPENDIX

APPENDIX A: TECHNICAL SPECIFICATIONS OF USED MATERIALS

Table A.1.Technical specifications of Arduino MEGA 2650 ADK (Arduino.cc)

Manufacturer	Arduino
Product Code	MEGA 2650 ADK
	
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
Analog Digital Converter	10 bits (1024 different values)
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Serial Data Interface	4 UART, I^2C, SPI
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
USB Host Chip	MAX3421E
LED Built-in	Pin 13
Length	101.52 mm
Width	53.3 mm
Weight	36 gr.

Table A.2. Technical specifications of XBee XB24-CZ7WIT-004 (Digi, 2017)

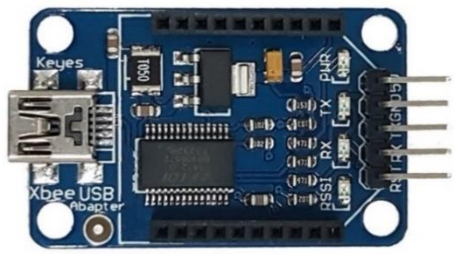
Manufacturer	Digi XBee® Zigbee
Product Code	XBee XB24-CZ7WIT-004
	
General Specifications	Integrated Wire Antenna
	2mW RF output power (+3dBm)
	1Mbps max. data speed
	Wired or Wireless configuration possibility
	120m Communication distance
	FCC Certificate
	Closed or open area configuration possibility
	128 bit encryption
RF Family Standard	802.15.4
Protocol	ZigBee
Input Voltage	3.3V @ 40mA
Digital I/O Pins	8
Analog Input Pins	6
Analog Digital Converter	10 bits
Data Speed	250kbps
Serial Data Interface	UART, SPI
Frequency Band	ISM 2.4 GHz
Configuration Methods	API or AT commands
Memory	32 KB Flash / 2 KB RAM
CPU	HC508
Clock Speed	Up to 50.3 MHz
Operating Temperature	-40°C ~ 85°C

Table A.3. Technical specifications of XBee XB24-BZ7WIT-004 (Digi, 2017)

Manufacturer	Digi XBee® Zigbee
Product Code	XBee XBP24-BZ7WIT-004
	
Specifications	Integrated Wire Antenna
	63mW RF output power (+18 dBm)
	1Mbps max. data speed
	Wired or Wireless configuration possibility
	1600m Communication distance
	FCC Certificate
	Closed or open area configuration possibility
	128 bit encryption
RF Family Standard	802.15.4
Protocol	ZigBee
Input Voltage	3.3V @ 295mA
Digital I/O Pins	8
Analog Input Pins	6
Analog Digital Converter	10 bits
Data Speed	250kbps
Serial Data Interface	UART, SPI
Frequency Band	ISM 2.4 GHz
Configuration Methods	API or AT commands
Memory	32 KB Flash / 2 KB RAM
CPU	HC508
Clock Speed	Up to 50.3 MHz
Operating Temperature	-40°C ~ 85°C

Table A.4. Technical specifications of XBEE USB Adapter Board (Parallax, 2015)

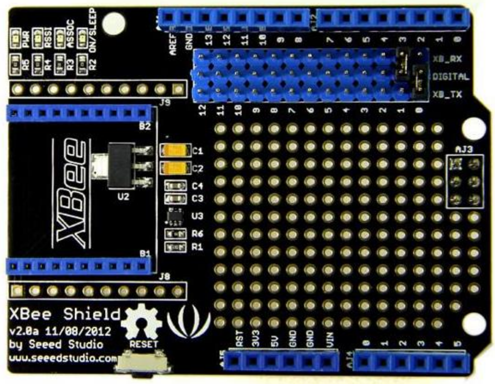
Manufacturer	Parallax INC.
Product Code	XBee USB Adapter Board



Specifications	USB 2.0 compatible serial interface
	3.3V and 5V compatible I/Os
	3.3V and 5V dual power outputs
	On-board 3.3V 250mA voltage regulator
	No external power needed
	256/128 bytes receive/transmit buffer
	FTDI Driver
	Works with X-CTU software from Digi Int
	XBee/XBee-PRO Modules can be adjusted

Table A.5. Technical specifications of XBEE Shield (Seeed, 2014)

Manufacturer	Seeed Studio
Product Code	XBee Shield-V2.2



Specifications	Compatible with all XBee modules.
	Compatible with most of Arduino models.
	LEDs for TX, RX, POWER and RSSI

Table A.6. Technical specifications of LM7905 (Texas Instruments, 2013)

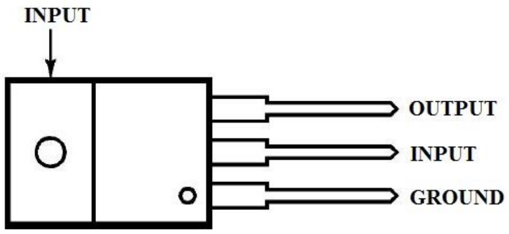
<table>
<tr><td>Manufacturer</td><td>Texas Instruments</td></tr>
<tr><td>Product Code</td><td>LM7905</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td rowspan="8">Specifications</td><td>Negative Voltage Regulator</td></tr>
<tr><td>Thermal, Short Circuit and Safe Area Protection</td></tr>
<tr><td>High Ripple Rejection</td></tr>
<tr><td>Maximum 1.5A Output Current</td></tr>
<tr><td>Available in Fixed 5-V, 12-V, and 15-V Options</td></tr>
<tr><td>4% Tolerance on Preset Output Voltage</td></tr>
<tr><td>0°C to +125°C Junction Temperature Range</td></tr>
<tr><td>Up to 230°C Lead Temperature for 10 s</td></tr>
</table>

Table A.7. Technical specifications of LM7805 (Texas Instruments, 2016)

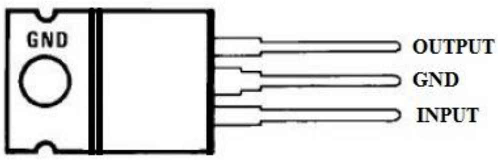
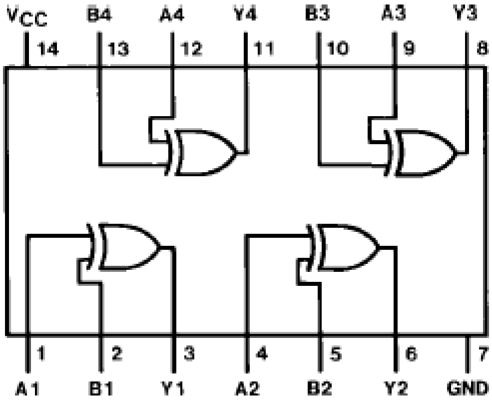
<table>
<tr><td>Manufacturer</td><td>Texas Instruments</td></tr>
<tr><td>Product Code</td><td>LM7805</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td rowspan="7">Specifications</td><td>Positive Voltage Regulator</td></tr>
<tr><td>Internal Thermal Overload, Short-Circuit and Safe Operating Area Protection</td></tr>
<tr><td>Maximum 1.5A Output Current</td></tr>
<tr><td>Available in Fixed 5-V, 12-V, and 15-V Options</td></tr>
<tr><td>Maximum 35 V DC Input Voltage</td></tr>
<tr><td>Maximum 150°C Junction Temperature</td></tr>
<tr><td>Up to 230°C Lead Temperature for 10 s</td></tr>
</table>

Table A.8. Technical specifications of 7486 Exclusive OR Gate (Fairchild, 2001)

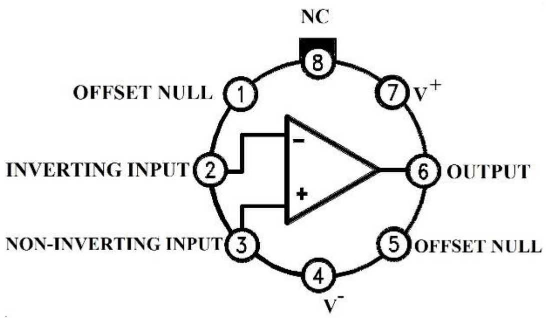
Manufacturer	Fairchield SemiconductorTM
Product Code	DM7486 (IC7486)



Definition	Quad 2-Input Exclusive-OR Gate
Supply Voltage	Maximum 7V
Input Voltage	Up to 5.5V
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Table A.9. Technical specifications of LM741 (Texas Instruments, 2015)

Manufacturer	Texas Instruments
Product Code	LM741



Protection	Overload Protection on the Input and Output
Application Areas	Comparator,Multivibrator,Amplifier,Integrator, Activer Filter
Supply Voltage	Min. ±10V, Nom. ±15V, Max. ±22V
Temperature Range	−55°C to +125°C

Table A.10. Technical specifications of 1 Way 5V Relay Module (Songle Datasheet)

Manufacturer	Songle
Product Code	SRD-05VDV-SL-C
	
Specifications	It can be used 1 way ON/OFF processes
	1 Way 5 V Relay Module
	Max. 10A @ 220 V_{ac} or 30 V_{dc}
Input Voltage	5V @ 20mA
Model of Relay	SRD
Nominal Coil Voltage	5 V DC
Structure (S)	Sealed
Coil Sensitivity (L)	0.36 W
Contact Form	C type, 1 form C
Contact Resistance	Maximum 100mW
Operation Time	Maximum 10msec
Release Time	5msec Max
Insulation Resistance	100 MW Min. (500VDC)
Max. ON/OFF Switching	300 operation/min (mec), 30 op/min(electrical)
Ambient Temperature	-25°C to +70°C
Operating Humidity	45 to 85% RH
Life Expectancy	107 operations. Min. (no load) (mechanically) 105 operations. Min. (electrically)
Weight	Approximately 10 grs.
Contact Material	AgCdO
Application Areas	Domestic appliance, office machine, audio, equipment, automobile, etc.
Trigerring Voltage	This type of relay is triggered by using 0V logical voltage.

Table A.11. Technical specifications of 4 Way 5V Relay Module (Songle Datasheet)

Manufacturer	Songle
Product Code	4 x SRD-05VDV-SL-C
	
Specifications	4 Way 5 V Relay Module
	Can be used 1 way ON/OFF processes
	Max. 10A @ 220 V_{ac} or 30 V_{dc}
Input Voltage	5V @ 20mA
Dimensions	10x7x3 cm
Weights	60gr
Contact Form	C type, 1 form C
Contact Resistance	Maximum 100mW
Operation Time	Maximum 10msec
Release Time	5msec Max
Insulation Resistance	100 MW Min. (500VDC)
Max. ON/OFF Switching	300 operation/min (mec), 30 op/min(electrical)
Ambient Temperature	-25°C to +70°C
Operating Humidity	45 to 85% RH
Life Expectancy	107 operations. Min. (no load) (mechanically) 105 operations. Min. (electrically)
Weight	Approximately 10 grs.
Contact Material	AgCdO
Application Areas	Domestic appliance, office machine, audio, equipment, automobile, etc.
Trigerring Voltage	This type of relay is triggered by using 0V logical voltage.

Table A.12. Technical specifications of 2x9V Transformer (Aslan Datasheet)

Manufacturer	ASLAN
Product Code	ASL 131209
	
Specifications	According to VDE 0570 / EN 61558
	Potted under vacuum
	Split winding
	Insulation Class 70°C/B
	Short circuit proof
	Approximately 160 gr weight
Primary Input Voltage	220 V
Secondary Output Voltage	2x9V
No-Load Voltage	2x12.1
Output Current	2x300 mA

Table A.13. Technical specifications of PCB Transformer (PanJit, 2007)

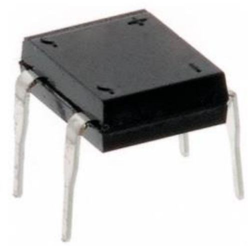
Manufacturer	PanJit Semiconductor
Product Code	DI154-T0
	
Diode Type	Single Phase
Voltage (Max)	400 V
Current-DC Forward (Max)	1.5 A
Reverse Current (At 25 C)	5uA
Mounting Type	THT (Through Hole Technology)
Operating Temperature	-55°C~+150°C

Table A.14. Technical specifications of ACS712 Current Sensor (Allegro, 2017)

Manufacturer	Allegro MicroSystems, LLC
Product Code	ACS712
	
Specifications	Low-noise analog signal path
	Designed for bidirectional current input from -30A to +30A
	66 mV/A sensitivity
	Isolated Current path
	Total output error 1.5% at TA = 25°C
	80kHz filtering band width which can be decreased
	Device bandwidth is set via the new FILTER pin
	5 μs output rise time in response to step input current
	66 to 185 mV/A output sensitivity
	2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8
	Output voltage proportional to AC or DC currents
	Nearly zero magnetic hysteresis
	Ratiometric output from supply voltage
Operating Voltage Range	3-5.5V
Weight	1.0gr
Operating temperature	40 °C to +85 °C
Accuracy	≤ 5%
Internal Resistance	1.2 mΩ

Table A.15. Technical specifications of Temperature/Humidty Sensor (Parallax, 2003)

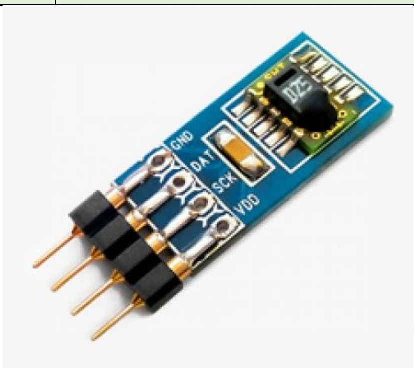
Manufacturer	Parallax Inc.
Product Code	Sensirion SHT11 Sensor Module (#28018)
	
Specifications	Consists of 14 bit Analog/Digital converter
	Low Power consumption (typically 30 µW)
	Consists of Serial communication unit
Operating Voltage	5-12V
Temperature Measurement Accuracy	±0.5°C @ 25°C
Humidity Measurement Accuracy	±3.5%
Operating Temperature	-40 °C to +125 °C

Table A.16. Technical specifications of Bluetooth HC06 Bluetooth Module (Core)

Manufacturer	Core Electronics
Product Code	HC06 Bluetooth Serial Port Module
	
Specifications	• Bluetooth 2.0+EDR Protocol (Slave Mode)
	• 2.4 GHz Communication Frequency
	• 10m Communication distance
Input Voltage	1.8-5 V @ 50mA (3.3V Recommended)
Asynchronous speed	2.1 MBps/160 KBps
Synchronous speed	1 MBps/1 MBps
Sensitivity	≤-80 dBm
Output Power	≤+4 dBm

Table A.17. Technical specifications of Panasonic Grid Eye Sensor (Panasonic, 2012)

Manufacturer	Panasonic
Product Code	AMG88
	
Definition	Infrared Array Sensor Grid-EYE
Vertical Pixel	8 pixels
Horizontal Pixel	8 pixels
Applied Voltage	3.3 V DC or 5 VDC
Amplification factor	High gain or Low gain
Temperature range of measuring object	0°C to 80°C (H=High), –20°C to 100°C (L=Low)
Operating temperature range	0°C to 80°C (H), –20°C to 80°C (L)
Storage temperature range	–20°C to 80°C (H), –20°C to 80°C (L)
Detection distance	Max. 5m
Viewing angle	Typical 60°
Current consumption	Typical 4.5mA (Normal Mode)
External interface	I^2C (fast mode)
Operating mode	Normal, Sleeping, Stand-by
Operating ambient humidity	15% to 85% R.H.
Operating atmospheric pressure	86 to 106 kPa
Frame rate	Typical 10 frames/sec or 1 frame/sec
Using Areas	• High performance home appliance (Microwave oven and air conditioner) • Energy savings in office (Airconditioning and lighting controls) • Digital signage • Automatic door and elevator

Table A.18. Technical specifications of IR Receiver Modules (Vishay, 2012)

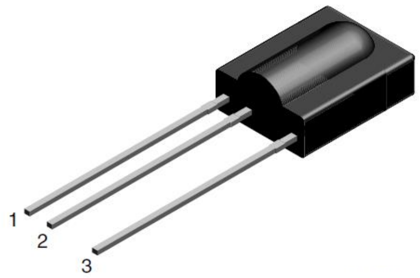
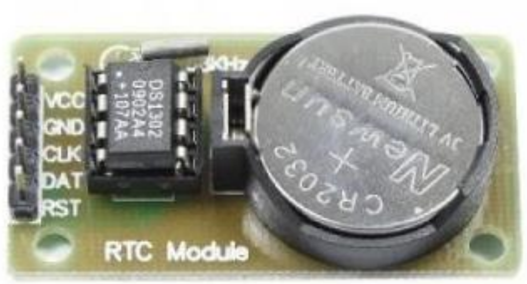
Manufacturer	Vishay
Product Code	TSOP1238
	
Specifications	1 = GND, 2 = VS, 3 = OUT
	38kHz operating frequency
Supply voltage	2.5 V to 5.5 V
Power consumption	10 mW at less than 85°C ambient temperature
Operating temperature range	- 25 to + 85 °C

Table A.19 Technical specifications of IR Receiver Transceiver Single Sensor Card (Vishay, 2012)

Manufacturer	Vishay
Product Code	IR-08H
	
Specifications	38kHz operating frequency
	Provides Logic 0 when detect objects between 2-40cm
Input Voltage	3.3-5V
Dimensions	44 mm x 18 mm

Table A.20. Technical specifications of Real Time Clock (RTC) Module (Maxim Integrated, 2015)

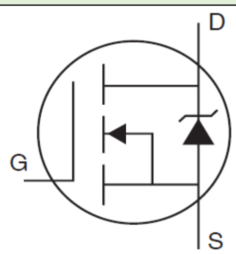
Manufacturer	Maxim Integrated
Product Code	DS1302



Specifications	Completely manages all time keeping functions
	Simple Serial Port Interfaces to Most Microcontrollers
	“Low Power Operation Extends Battery Backup Run Time
	8-Pin DIP and 8-Pin SO Minimizes Required Space
Input Voltage	2V @ 20mA
Operating Temperature	-40 °C to +85 °C

Table A.21. Technical specifications of MOSFET (International Rectifier, 2004)

Manufacturer	International Rectifier
Product Code	IRF630N



Specifications	N Type Power MOSFET
	200 V Drain-to-Source Breakdown Voltage
	Drain Source Resistance RDS(on) = 0.30Ω
	Drain Current ID = 9.3A
	Up to 175°C Operating Temperature

Table A.22. Technical specifications of Motion Detection Sensor (Gizmo, 2016)

Manufacturer	e-Gizmo Mechatronix Central
Product Code	HC-SR501

Specifications	• Sx and Tx potentiometers on the sensor • Sx potentiometer adjust the sensing distance • Tx potentiometer adjust the logic 1 duration
Operating Voltage	5-20V DC
TTLOutput	3.3V, 0 V
Power Consumption	65 mA
Sensing Distance	3-5m
Sensing Angle	140°

Table A.23. Technical specifications of 40W LED Driver (MeanWell, 2016)

Manufacturer	Mean Well
Product Code	MW LPF-40D-12

Input Voltage Range	90 ~ 305VAC
Input Frequency Range	47 ~ 63Hz
Power Factor	PF≧0.95/230VAC at full load
Efficiency	84%
Input AC Current	0.3A / 230VAC
Output Voltage	12 V DC
Output Rated Current	3.34 A
Output Rated Power	40.8 W

Table A.24.Technical specifications of Photovoltaic Solar Panel (LCS, 2011)

Manufacturer	LCS Solarstrom AG
Product Code	LCS-M250-JA/SI

Dimensions /Weight	1650x991x40mm / 19.5kg
Cell Number	60 (Monocrystalline)
Maximum Power	250 Wp -0/+5 Wp
Voltage / Current at Pmax	30.96 V / 8.07 A
Short Circuit Current/ Open Circuit Voltage	8.62 A / 37.92 V
Max. System Voltage	1000 V
Fuse Rating	15 A
Module Application/Working Degree	+45 Degree

Table A.25.Technical specifications of Stepper Motor (SANXING)

Manufacturer / Product Code	SANXING / FD-24-A1

Input Load	24V DC
Max Load	6000N/Push 4000N/Pull
Speed	4mm/s
Duty Cycle	10% Max: 2min/18min

Table A.26. Technical specifications of 16x2 LCD Screen (Seeed)

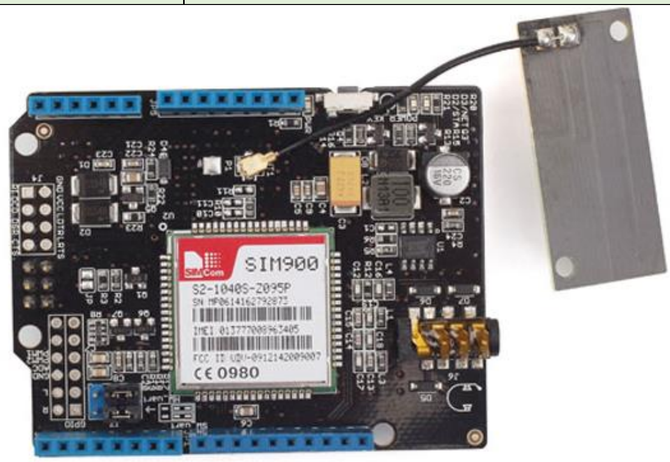
Manufacturer	Seeed Studio
Product Code	Grove - LCD RGB Backlight
	
Specifications	RGB Backlight
	I^2C communication
	Built-in English fonts
	16x2 LCD
Input Voltage	5V
Operating Current	<60mA
CGROM	10880 bit
CGRAM	64x8 bit

Table A.27. Technical specifications of 4x4 Membrane Keypad (Parallax, 2011)

Manufacturer	Parallax Inc.
Product Code	4x4 Matrix Membrane Keypad (#27889)
	
Maximum Voltage	Up to 24 VDC
Maximum Current	30 mA
Interface	8-pin access to 4x4 matrix
Operating Temperature	0 to 50°C
Keypad Dimension	6.9 x 7.6 cm
Cable Dimension	2.0 x 8.8 cm

Table A.28. Technical specifications of GSM/GPRS Shield V3.0. (Seeed)

Manufacturer	Seeed Studio
Product Code	GSM/GPRS Shield V3.0**.**



Specifications	GPRS Shield is used for connection to GSM/GPRS cell phone network
	850/900/1800/1900 MHz 4 band support
	2-in-1 headset jack
	Built-in 3.5mm TRRS headphone/ microphone input
	Convenient external SIM card holder
Compatible	Arduino UNO/Seeeduino directly ; Other main board via jumpers
Input Voltage	5V (5V pin) / 6.5-12V (Vin pin)
SIM900 Certifications	CE, IC, FCC, ROHS, PTCRB, GCF, ICASA, REACH, AT&T
Protocol Support	0710 MUX, embedded TCP/UDP protocol, FTP/HTTP, FOTA, MMS, embeddedAT
Communication Support	Standard - GSM 07.07 & 07.05 and Enhanced - SIMCOM AT Commands
Power Consumption	1.5 mA (sleep mode)
Selectable interface	UART, Software serial interface
Battery	Exclude
Dimensions	100mm x 65mm x 30mm
Weight	47 g.
Operating Temperature	-40 °C to +85 °C

Table A.29. Technical specifications of Ethernet Shield (Wiznet, 2011), (Hanrun), and (Dfrobot)

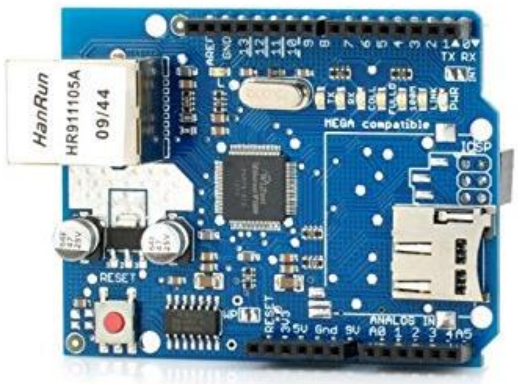
Manufacturer	Wiznet, Hanrun,Dfrobot
Product Code	Ethernet Shield
	
Specifications	Ethernet Shield has Wiznet W5100 Ethernet Chip
	Ethernet Shield has SD card
	Compatible with Arduino Uno and Arduino Mega
	Arduino communicates with both the W5100 and SD card using the SPI bus
	Digital pins 50, 51, and 52 are used for SPI connection on the Mega
	Digital pins 11, 12, and 13 are used for SPI connection on the Uno
	In both Uno and Mega, selection pin of Wiznet W5100 is pin 10 and selection pin of SD Card is pin 4
	Uses standard Arduino Ethernet drivers
	Supports 4 independent sockets simultaneously
	Not support IP Fragmentation
	Internal 16Kbytes Memory for Tx/Rx Buffers
	The shield is connected to your computer or a network by using CAT 5 or CAT 6 cable and RJ45 connector produced by HanRun.
	Support Hardwired TCP/IP Protocols (TCP, UDP, ICMP, IPv4 ARP, IGMP, PPPoE, Ethernet)

Table A.30. Technical specifications of Fingerprint Sensor (Seeed)

Manufacturer	Seeed Studio
Product Code	Grove-Fingerprint Sensor
	
Specifications	Up to 162 fingerprints can be memorized
	DSP AS601 chip is used as control unit
Input Voltage Range	3.6~6.0 V
Maximum Input Current	120mA
Fingerprint Detection Speed	≤ 1 sec
Baud rate	9600, 19200, 28800, 38400, **57600** bps
Communication Interface	TTL Serial
Operating Temperature	-20 °C to +50 °C

Table A.31. Technical specifications of Flame Sensor Module (Cytron, 2015)

Manufacturer	Cytron
Product Code	Flame Sensor Module
	
Specifications	Detecting fire with wavelength between 760 nm and 1100 nm
	Sensitivity adjustment possibility
	Providing analog and digital output
Operating Voltage	5V
Detection Range	20cm (1V) – 100cm (4.8V)
Dimension	18 mm x 12 mm

Table A.32. Technical specifications of DS18B20 Temperature Sensor (Keyes)

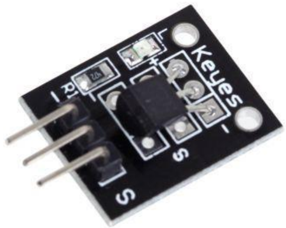
Manufacturer	Keyes DIY Robot Co.
Product Code	KEYES 18 b20
	
Specifications	DALLAS DS18B20 digital temperature sensor is used in this sensor module.
	Measures Temperatures from -55°C to +125°C
	±0.5°C Accuracy from -10°C to +85°C
	Programmable Resolution from 9 Bits to 12 Bits
	Each Device Has a Unique 64-Bit Serial Code Stored in On-Board ROM

Table A.33. Technical specifications of MQ2 Gas Sensor Module (Seeed, 2015)

Manufacturer	Seeed Studio
Product Code	MQ-2 Gas Sensor Module
	
Specifications	It can be detected H_2, LPG, CH_4, CO,Alcohol, Smoke, Propane
	Good sensitivity to Combustible gas in wide range
	Long life and low cost
Input Voltage	5V @ 150mA
Heater Resistance	33 Ω
Power Consumption Range	0.5 mW-800 mW
Operating Temperature	-20 °C to +50 °C

Table A.34. Technical specifications of Serial Camera Module (Adafruit, 2018)

Manufacturer	Adafruit
Product Code	TTL Serial JPEG Camera
	
Input Voltage	5V
Module size	32mm x 32mm
Image sensor	CMOS 1/4 inch
CMOS Pixels	30M
Pixel size	5.6um*5.6um
Output format	Standard JPEG /M-JPEG
White balance	Automatic
Exposure	Automatic
Shutter	Electronic rolling shutter
SNR	45DB
Dynamic Range	60 dB
Frame speed	640*480 30fps
Viewing angle	60 degrees
Monitoring distance	10 meters, maximum 15meters (adjustable)
Image size	VGA 640*480), QVGA320*240), QQVGA(160*120)
Baud rate	Default 38400, Maximum 115200
Current draw	75mA
Communication	3.3V TTL （Three wire TX, RX, GND on 2.0mm pitch connector