VAASAN AMMATTIKORKEAKOULU
VASA YRKESHÖGSKOLA
UNIVERSITY OF APPLIED SCIENCES

Zhu Jiang

DESIGN AND IMPLEMENTATION OF A SMART METER PROTOTYPE USING AVR465 MICROCONTROLLER

Technology and communication

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VAASAN AMMATTIKORKEAKOULU
VAASA UNIVERSITY OF APPLIED SCIENCES
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ABSTRACT

Author	Zhu Jiang
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The purpose of this thesis is aiming to develop a fully functioned and accurate smart meter in home automation system, which fulfils the requirements of home energy conservation and control in energy efficient strategy. Through smart meter applications, people can understand how energy is used and how to monitor and control the usages.

Technique of transmitting data via power line (PL) is used already in many energy applications. This work discusses the current state of the power line carrier communication and the complement of solid-state relay, which is designed as external part for smart meter application.

This design based on the single-chip AVR465 which is a microcontroller chip used for single phase power meter with tamper logic. The core can store large amounts of information and measurement with the measuring results in real-time analysis, comprehensive and make a judgment apparatus. The design has been implemented with C language and the related applications have been implemented using QT, Javas Script, HTML, PHP, jQuery, mySQL database and FTP protocol. Furthermore, the measurements have were correct and within the range of accuracy.

ACKNOWLEDGEMENT

This thesis was done at Vaasa University of Applied Science. I have received an excellent guidance. I appreciate all the supports that I got and the inspiration during my study.

At the beginning I would like to give special thanks for my supervisor Dr. Smail Menani, he gave me a full supports from every aspects. Under his guidance I could have a very clear clue to work on the project and figure out the problems occurred in my study.

Besides my supervisor, I would like to thank all the teachers who supported my study and helped me. I could not successfully complete my study without their guidance and help. Thanks for this great opportunity that I could get the chance to do this project which gave me a lot of treasure practicing experiences in my future career. Jani mäki gave me a lot of helps on project technical support as my colleague. I was confused at the beginning on communication protocol design and related programming skills that I need to use. After study and test I got to know clearly on how to move forward.

My sincerely thanks go to my family. They support me all the time to complete my study. Also to all the others who accompanied me during my study life in Vaasa, you gave me a wonderful and memorable time in my life.

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LIST OF ABBREVIATIONS

MCU	Microcontroller Unit
HMI	Human-Machine Interface
PLC	Power Line Carrier
SSR	Solid State Relay
DCSK	Differential Code Shift Keying
AFE	Analog Front End
ADC	Analog Digital Converter
DAC	Digital Analog Converter
DDS	Data Distribution Service
IOT	Internet Of Things

1. INTRODUCTION

1.1 Background

The world has been growing fast and our life has been developed relies on high efficiency energy usage. Energy has become increasingly important in all areas of our society. Efficiency and flexibility are the key ingredients in finding a solution for the usage and production of electricity. It has been important in the past with examples of both having it and lacking it. As population growth, rising standard of living, climate change, increasing importance of electricity and increasing of energy efficiency. We have great challenges of the future in terms of smart energy usage. Energy saving is not the main reason that electricity retail companies aimed for smart meters. The remote reading and controlling can help them reduce the manpower costs and it is also become a very important national strategy related to every one living standard and society safety. Smart meters can quickly connect to customers and let them know where is the money go and how does it consumed. Electricity retails can use different tariffs for importing energy and for exporting energy from self-generation of their customers with solar panels and micro generators.

On the other hand, Smart meter with remote reading and remote control can also raise a serial of potential problems, such as protection privacy, cybercrime, vulnerability to technical calamities as well as the handling and storage of huge amounts of data. Generate a radiation which can be harmful for body but not yet proved by medicine research. Smart meter installation might costs more than 1000 euros per customer while itself consuming a certain amount of electricity energy. All of those problems can be further studied and developed in the future.

Figure 1 1

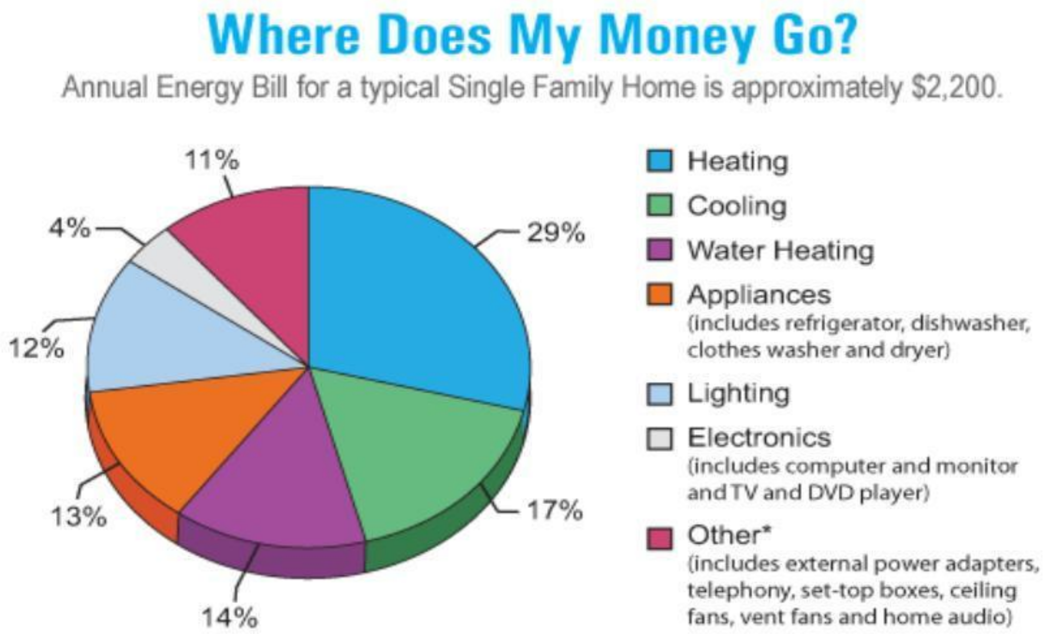


Figure 1

Figure 1. Energy consumption for a typical family

1.2 Introduction of smart meter

The so-called home automation smart meter is an application of device based on microcontroller AVR465 and related peripheral devices, which can store a large amount of measurement information andreach a real-time automatically record consumption of electric energy from appliances in intervals of an hour or less and back to the utility for monitoring and billing. The design of the power meter utilizing computer technology, communication technology, etc. to read and reduce the energy consumption of the acquisition, processing concentrated in one, saving costs and human resources, improve working efficiency and adapt to the modern needs of IoT.

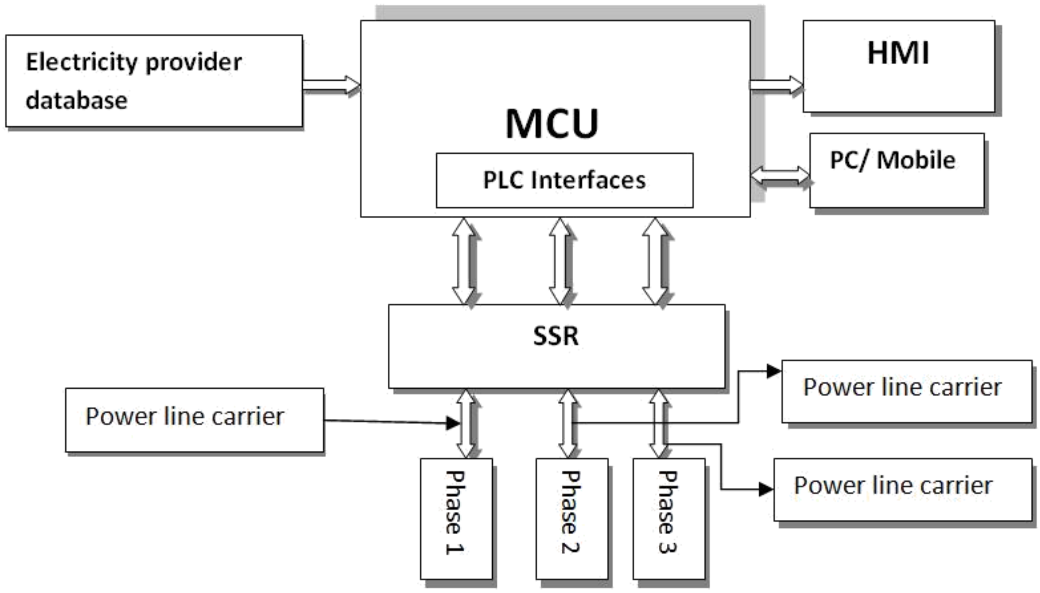


Figure 2

Figure 2. Smart meter system overview

Figure 2 shows the relation of different parts via smart meters to have a running process,databases can be collected from MCU via AVR Studio software, detail real-time data information shows on HMI devices. QT was used for design HMI on Mobile operating system. Data distribution service is addressing the needs of smart meter management, and other big data applications for the future development for instance wireless communication modules.

DDS is networking middleware which implements a publish model for sending and receiving data, events and commands among the nodes.

Web application for Real time monitoring system used by Ftp, File transfer protocol to transfer data from MCU to computer meanwhile update instant data between PC and MCU. Webpage was created by HTML5 and jQuery.

2. TECHNIAL THEORETICAL FRAMWORK

2.1 Smart meter design functional requirements

The former parts designed by an AC power exemplar, the main requirements of the design are as follows:

1. The AC power meter enables the measurement of single-phase AC electric energy.

2. Meter parameters: Rated voltage 220V, rated current of 5A, the maximum cur-rent of 10A, the maximum count of the capacity: 99999.99Kw.h;

3. Able to measure and display the current RMS power, voltage and current;

4. Display the current data, with a time-measurement function;

5. With a PC serial communication interfaces and the keyboard can be used to control, easy to operate;

6. Power pulse output measurement;

7. Does not lose power outage data;

8. Big data and Machine learning algorithms;

9. Fast, efficient and safe;

2.2 PLC (Power Line Communication Carrier)

PLC stands for power-line carrier communication, which is used simultaneously for AC electric power transmission. Here used for electric power distribution to consumers. Power line carrier is the technique used to send data over power lines.

For ensure the proper microcontroller's capacity we need to modulate high frequency carrier on the low frequency (50Hz) power lines to send data over the same physical wire lines. PLC has a variable bandwidth and flexible partitioning of digital and analog data, backed with a formidable capability in the system. DCSK (Differential Code Shift Keying) spread spectrum is an important method used to provide robust communication.

2.3 DCSK

DCSK(Differential Code Shift Keying) is Yritan patented spectrum modulation technology. The three graphics illustrate how DCSK works. Each symbol was divided into 15 bits. The first graphic shows the original none shifted symbol with the fist bit represented by "0000" in decimal. The second graphic shows when first cyclic bit shifted, the shifted symbol read as 0000. The third graphic shows when 8 bits shifted, the shifted symbol will read as 1000, this is an accurate method to reduce pulse noise interfering while transmitting and receiving signals.

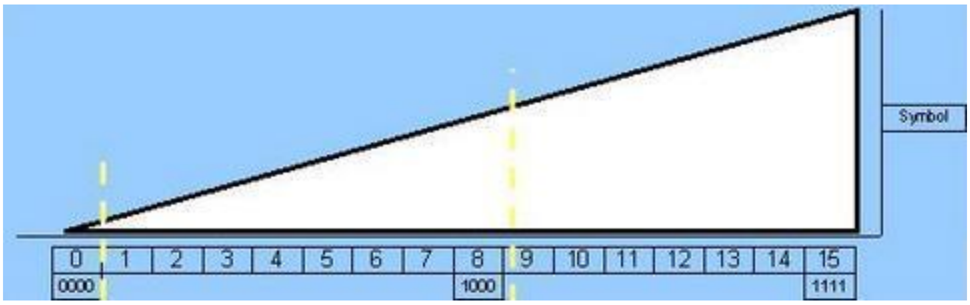


Figure 3

Figure 3 None shifted symbol

Figure 4

Figure 4 Shifted symbol

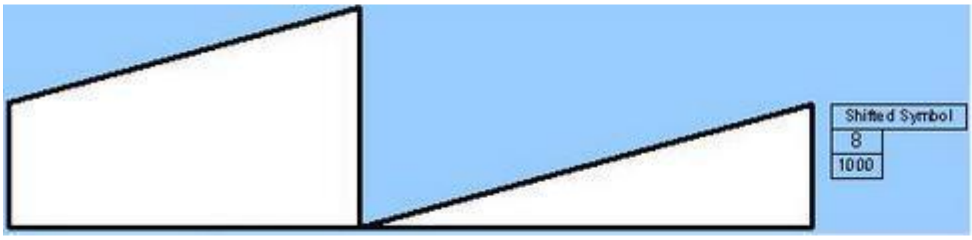


Figure 5

Figure 5 Shifted symbol 8

2.4 Power measurement

For DC power:$P_{dc} = U_{dc} \times I_{dc}$;

$P_{dc}$is the power of transmission on the power line.
$U_{dc}$is the voltage of the power line.
$I_{dc}$is the current of the power line.

When we measure the power of an appliance, we express the power in joule per second.

For AC power: Based on DC power the instantaneous electric power in an AC circuit is given by$P = U \times I$, but these quantities are continuously varying. So weneed to use power triangle to calculate AC power which can represent the equality of DC values.

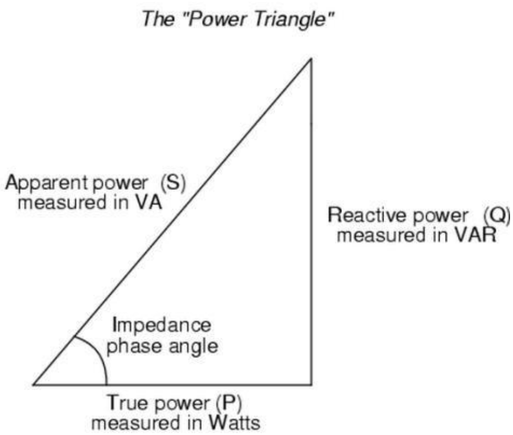


Figure 4 Power Triangle

Figure 4 illustrate the relation of apparent power to true power and reactive

α is the impedance phaseangle between apparent power and true power.

AVR represented Voltage-Amps-Reactive.

Calculation for AC power is

$$P_{AVR} = S \times Q \times P \times \cos\alpha = U_{AVR} \times I_{AVR} \times \cos\alpha$$

In the smart meter, usually electric company only counts active power into bills. The power supply companies assume the power factor of a regular home is within limits so they do not take apparent power into account.

2.5 Three-phase power calculation

Most AC power is generated and distributed as three phase power where the sinusoidal voltages are generated out of phase with each other. Based on Watt's law we can calculate three phase power as Watt's Law:

$$W = V_{avg} \times A_{avg} \times \sqrt{3} \times \cos\theta$$

Where:

W = wattage (watts);

V_{avg} = average voltage of the three separate phases(volts)

A_{avg} = average current of the three separate phases (amps)

$\cos\theta$= average power factor or the three separate phases.

$\sqrt{3}$= 1.732 a constant necessary with 3 phases.

3. IMPLEMENTATION

3.1 Solid-State Relays

A Solid -State-Relay (SSR) is an electronic switching device that switches on or off when a small external voltage is applied across its control terminals. SSR consists of a sensor which responds to an appropriate input and a coupling mechanism to enable the control signal to activate this switch without mechanical arts. This relay is used to switch either AC or DC to the load.

VO14642AT is high speed normally open (1 form A) solid state relay. The relays can be configured AC/DC operation. Load voltage 60V and load current 2A DC configuration.

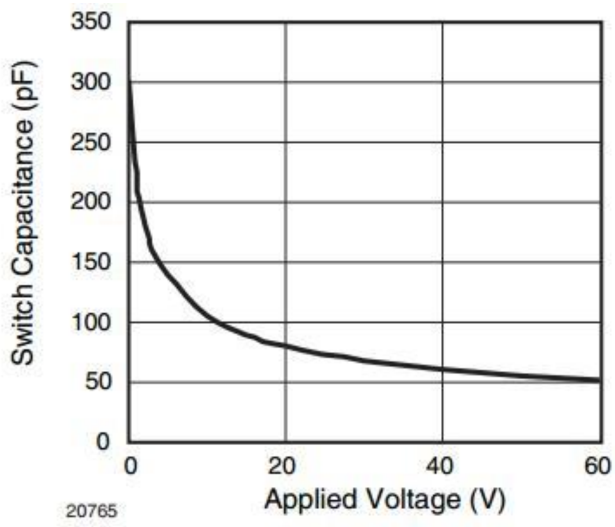


Figure 5

Figure 5 Switch capacitance vs applied voltage

From graphic 5 we can see the switch capacitance changes during applied voltage vary. The relay has very stable capacitance since applied voltage reaches the maximum 60 volts. It was used in this project to protect extra current or voltage to protect devices.

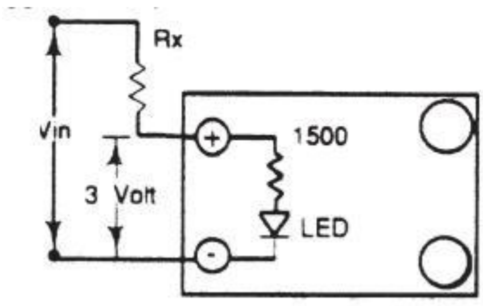


Figure 7

Figure 6 Solid State relay application

Usually higher voltages lead higher current, since 1.4mA are required to turn on the relay but increasing the input voltage will unnecessarily increase this current, an external resistor added in series with the input can draw the input voltage to fit for the application circuit in protection purpose. From figure 6, the voltage at input is approximately 3 volts. We get:

$$R_x = \frac{(V_{in} - 3)}{0.0014}$$

If odd value, pick the lower resistance value then calculation of wattage required is

$$W = \frac{(V_{in} - 3)}{R_x}$$

Under all conditions, the SSR will draw:

$$\text{Amps} = \frac{(V_{in} - 1)}{R_x + 1500}$$

For 60VDC input in smart meter, an external resistor is added:

$$R_x = \frac{60 - 3}{0.0014} = 40.71 Ohms$$

This solid state relay shield in the project provided power meter AC currency control in accuracy condition due to its minimum electrical noise. It has zero voltage turn on and zero current turn off, which provided power meter for minimum electrical disturbances. For the fast switching, the time is less than 100 us, which improved the accurate of AC control.

3.2 Yritan IT800D

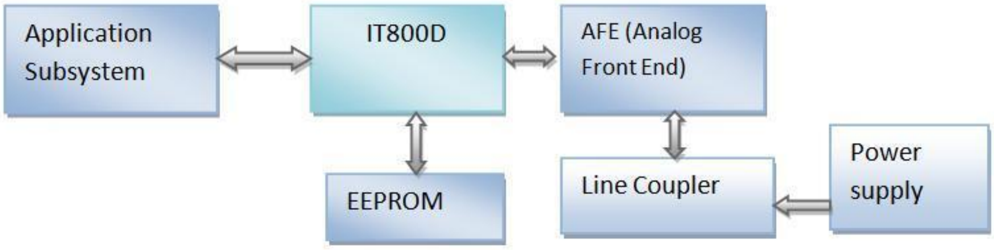


Figure 8

Figure 7 IT800D PLC General Block Diagram

Figure 6 shows the principle of IT800D PLC devices" block. Base on the core processers IT800D, power source generated suitable current via line coupler to distributed circuit which has analog front end and including an AD converter so that digital signal can be received by microcontroller. The microcontroller used in this project has 8 channel multiplexed 10 bits analog to digital converter. The application subsystem part contains implementation of the specific applications provides the user interface for devices such as switches, thermostats etc.

3.3 Active Power Measurement

The active power is defined as a power that used by a device to produce useful work. It is mathematically into calculation of integral of voltage, Ut, time current I, as following equation:

$$P = \frac{1}{T}\int_0^T u_t \times i_{(t)} dt \equiv U \times I \times \cos\alpha$$

Here U and I are respective voltage and current Root mean square values. Alpha is the phase lag between current and voltage. The value is valid for both sinusoidal and distorted waveforms. MCU uses 32-bit data type, which stored result as floating point when meter calibrated. Power unit is watts. The same as measured current and voltage, which has an equation as:

$$U_{RMS} = \sqrt{\frac{\sum_{n=0}^{N-1} u^2(n)}{N}}$$

Voltage RMS(Root-Mean-Square) in time domain, here u(n) is voltage samples, for current is the same equation, current samples is i(n). Usually the load circuit voltage is 230v, but it is out of the microcontroller's measure scope. We need to adjust voltage into smaller not surpass as 3V safety voltage to microcontroller by adding resister ladder into the circuit.

3.3 AFE (Analog Front End)

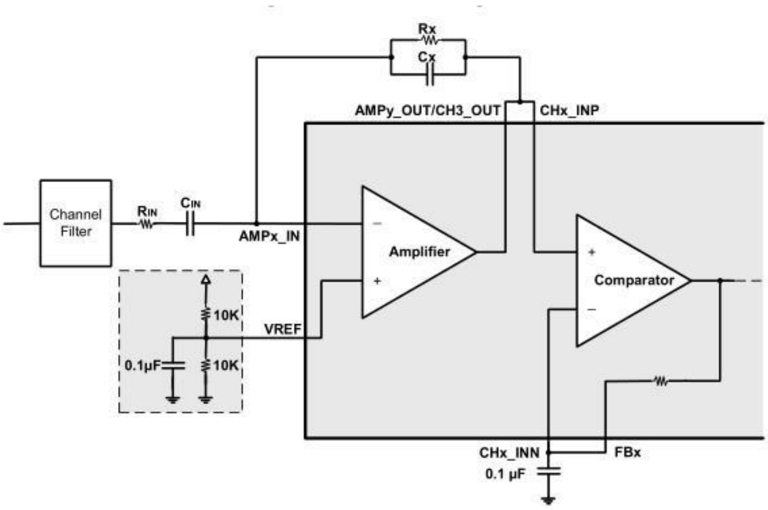


Figure 9

Figure 8 ADC Block Diagram

AFE is located between IT800D block and line coupler block. AFE includes a DAC (Digital to Analog Converter) in the transmission path and preamplifier and a ADC (Analog to Digital Converter). In the figure 7, VREF input is a single in-put, which is common to all three ADC units. Based on Nyquist sampling theorem:

$$f_s = \frac{f_{clk}}{128 \times 13} = \frac{4000000Hz}{1664} = 2403.5Hz$$

Sampling frequency is 2403.85 Hz, which is enough for the smart meter 7.5k Hz capacity.

4. ELECTRIC SHOCK HAZARD

4.1 Safety environment

Section	Includes	Continuous	Peak
Front End	Operational amplifiers (1)	0.2 mA	0.2 mA
Microcontroller	AVR (Active Mode, 4 MHz) (2)	1.8 mA	3.5 mA
LED	All LED's (each about 1 mcd brightness)	None (3)	3.0 mA
Display	Display counter (400 Ω coil impedance)	None (3)	7.5 mA

Table 1-Typical Current Consumption of Main meter Section

The graphic 8 shows the connection between microcontroller and external hard ware. From the graphic 8, we can see AVR 456 microcontroller has no insulation from the line voltage. Hence, the meter sections contain high voltages and even the low-voltage output of the power supply is connected to the main board, this will cause dangerous for people to touch it without any protection cover. Hence, meter must be enclosed in a nonconductive casing to avoid accident electric shock hazard. In order to make sure that interfere signals from high voltage power meter are isolated, a galvanic isolation barrier is created in this project. Il717 is chosen as a galvanic isolation of 3kv between input and output from ADC to controller.

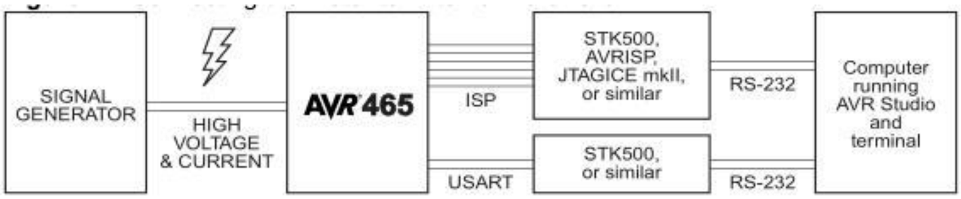


Figure 10

Figure 9. Connecting meter to external hard ware

4.2 Galvanic isolation IL717

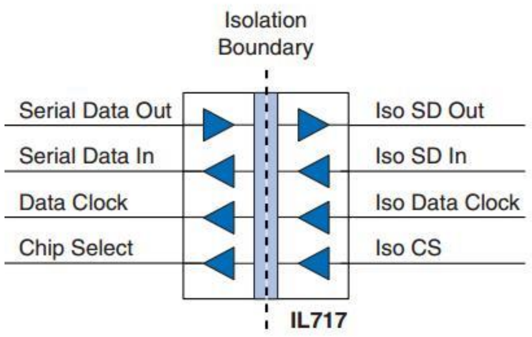


Figure 11

Figure 10.IL717

The IL717 is a good option for isolation, it isolated the control bus from the microcontroller. The clock of system just located on the isolated side.

4.3 Power supply

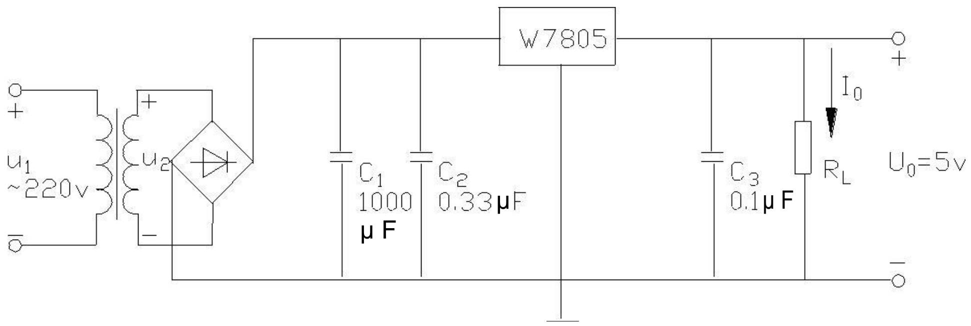


Figure 12

Figure 11.+ 5V power supply design

The power supply circuit is a prerequisite and key to the whole system to keep stable. The design used for homemade power supply, the 220V AC power into AC power transformer by low pressure, and then after the bridge rectifier circuit isrectified and filtered at both ends of the fixed three-terminal regulator to form a not very stable DC voltage, the DC voltage regulators and capacitor through W7805 frequency compensation, then the output of the power supply produced a high accuracy, good stability DC output voltage. Designed power supply schematic shown in Figure 10.

We keep the size of capacitor as small as possible, since it dictates how much power is drawn from the mains lines. The minimum size of the capacitor is derived from the basic functions of stored charge (Q = CU) and current (I = Q/t).

Parameter	Value	Note
System clock	4MHz	External crystal by default
Maximum Current	10A	External amplifier chops above 10A
Nominal Voltage	230V	Varistor chops signals above 250V
Current Gain Ranges	1.25 / 10 / 69	

Table 2 Hardware DefaultsHardware Defaults

5 SOFTWARE

Software has been developed in a demo code, which is used IAR EWAAVR 3.10C compiler in C language code.

```
unsignedintCRC(unsignedintchksum,unsignedcharbuffer);
voidInitialise(void);
voidInitGainControl(void);
voidReadCalibration(void);
voidSetGain(unsignedcharChannel,unsignedcharLevel);
voidSetPulse(floatPower);
intmain(void);staticintuart_putchar(charc,F
ILE*stream);staticintuart_getchar(FILE*stre
am);
```

This code has function property illustrated current and voltage gain control and also read the calibration and adjust it by using formula of coefficient calibration.

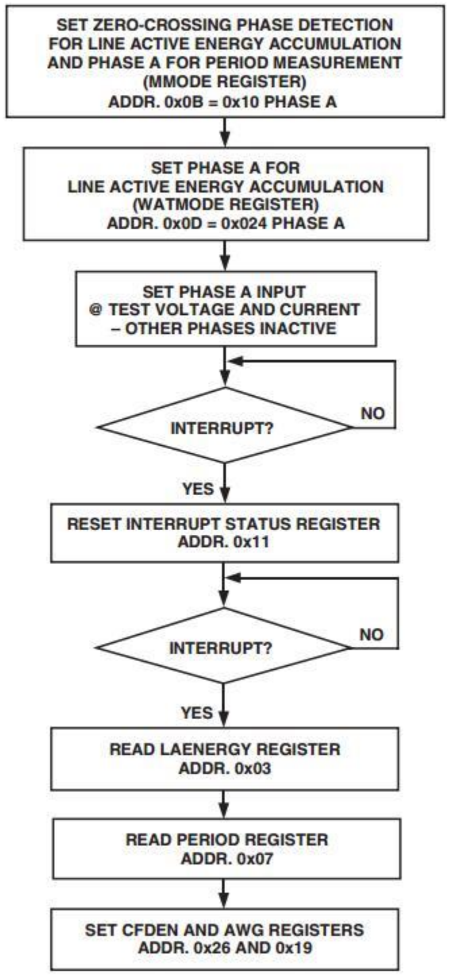


Figure 13

Figure 12. Active energy gain calibration procedure

```
if(GainHysteresis)
{
Flags=Flags&(0xFF-MOREGAIN0);
Flags=Flags&(0xFF-MOREGAIN1);
GainHysteresis--;
}
else
// Gain control.
switch(Index)
{
case1:// Step down gain, if RAW sample has saturated at high
limitif(Sample[Index].Fresh>SAT_HI)
Flags=Flags|LESSGAIN0;
// Step down gain, if RAW sample has saturated at low limit
if(Sample[Index].Fresh<SAT_LO)
Flags=Flags|LESSGAIN0;
// Don't increase gain if FILTERED amplitude above threshold
if(Sample[Index].Filtered>AMP_LO)Flags=Flags&(0xFF-
MOREGAIN0);
```

```
break;
case2:// Step down gain, if RAW sample has saturated at high
limitif(Sample[Index].Fresh>SAT_HI)
Flags=Flags|LESSGAIN1;
// Step down gain, if RAW sample has saturated at low limit
if(Sample[Index].Fresh<SAT_LO)F
lags=Flags|LESSGAIN1;
// Don't increase gain if FILTERED amplitude above threshold
if(Sample[Index].Filtered>AMP_LO)Flags=Flags&(0xFF-
MOREGAIN1);

}
//Delay = [ 360 degrees * f(mains) ] / [ 3 * f(sampling) ]
```

6. CALIBRATION AND VALIDATION

In fact all the meters have more or less tolerance figures for components using are 5%. It is necessary to calibrate the meter before it is in using. All the calibration coefficients are calculated for each meter individually. The testing result is stored in EEPROM chip. Phase displacements are the problem in the test. At 2400Hz sampling frequency, the delay is 1/2400=0.42ms. So at 50Hz main frequency the phase difference is of 360*(50Hz/2400Hz) = 7.5 degrees. After a research this phase displacement can be adjusted by using linear interpolation. Equation of the effective of phase calibration coefficient is:

$$Z = \frac{PCC}{65536} \times \frac{360^{\circ} \times f_M \times 128 \times 13 \times 3}{f_{CLK}}$$

PCC is the phase calibration coefficient and f_M is the main frequency, f_{CLK} is the system clock frequency. For 16 bit phase coefficient treated as unsigned.

ADDR.	+ 0x00	+ 0x01	+ 0x02	+ 0x03	+ 0x04	+ 0x05	+ 0x06	+ 0x07
0x00	PCC0		PCC1		PCC2		ILG0	
0x08	ILG1		ILG2		ING0		ING1	
0x10	ING2		UG		MC		DPC	
0x18					CRCW		CRC16	

Table 3 Calibration layout in EEPROM

7. CONCLUTION

This thesis has introduced smart meter home automation system and the complement of developing smart meter shields as advantage of accuracy and stable ability. Solid state relay for smart meter has successfully applied in working condition. Different measurement methods have showed in the thesis. There is no absolutely perfect thing exist in the world, which stimulus us always exploring more efficient new methods to develop our products.

Microcontroller is a key factor for the power meter due to its stability and powerful function. There are still a lot of aspects can be developed. In the future smart meter can integrate into smart appliances not only household application, but also industrial area. Also new technology can use and replace the old one. Such as KNX standard has higher requirement of smart meter application and also hard-ware design. Some problems occurred during the testing part. We always need to learn new technology to enhance ourselves.

This is a very practical project as a thesis. In the future, a wireless control module and link to national smart grid can be built up. The automation system can add more sensors that have more functions work for our life everywhere. I do believe our world will become smarter and electrical based efficient life style.

8. APPENDIX A:

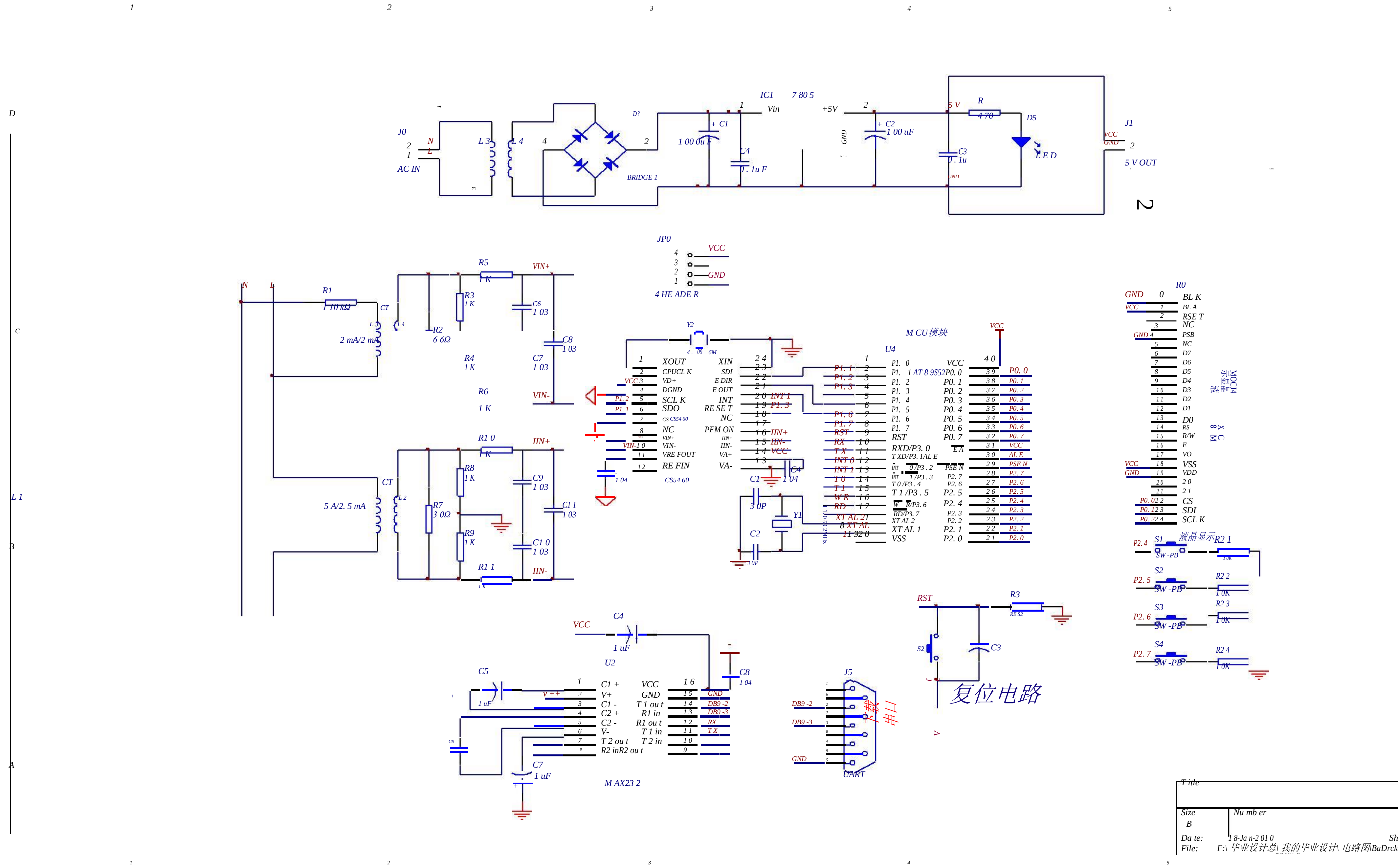
Software library: AVR465.H

```
/*************************************************************************
***
*
* Atmel Corporation
*
* File              : AVR465.h

* Compiler          : IAR EWAAVR 3.50C
* Revision          : $Revision: 1.31 $
* Date              : $Date: Tuesday, June 02, 2014 11:12:32 UTC $
* Updated by        : $Author: *
* Support mail      : avr@atmel.com
*
* Supported devices : This example is written for the ATmega88. Firmware
*                     as such should fit in any other AVR with 8kB Flash.
*
* AppNote           : AVR465: Power/Energy Meter with
*                     Tamper Detection.
*
* Description       : Header file for main program.
*
**************************************************************************
*/

//////////////////////////////////////////////////////////////////////////
//
//  F U N C T I O N   P R O T O T Y P E S
//////////////////////////////////////////////////////////////////////////
//

unsignedintCRC(unsignedintchksum,unsignedcharbuffer);
voidInitialise(void);
voidInitGainControl(void);
voidReadCalibration(void);
voidSetGain(unsignedcharChannel,unsignedcharLevel);
voidSetPulse(floatPower);
intmain(void);staticintuart_putchar(charc,F
ILE*stream);staticintuart_getchar(FILE*stre
am);


//////////////////////////////////////////////////////////////////////////
//
//  D E F I N E S
//////////////////////////////////////////////////////////////////////////
//

// Use internal voltage reference + external stabilising capacitors
#defineADC_VREF_TYPE0xC0

// Masks for output signals
```

```
//
//  PORT | MASK | BIT7 | BIT6 | BIT5 | BIT4 | BIT3 | BIT2 | BIT1 | BIT0 |
//  -----+------+------+------+------+------+------+------+------+------+
 //   B  | 0x03  |   0  |  0   |    0 |    0  |   0  |    0  |   EP | DUTY |
 //   C  | 0x18  |   0  |  0   |    0 |REVDIR| EARTH|    0  |    0 |    0 |
 //   D  |   0xFC |  DPN | DPP  | GAIN | GAIN  | GAIN | GAIN |    0 |    0 |
#defineDUTY0x01
#defineEP0x02
#defineEARTH0x08
#defineREVDIR0x10
#defineDPP0x40
#defineDPN0x80
#defineDIRB0x03
#defineDIRC0x18
#defineDIRD0xFC
```

```
// Gain stage control constants
#define       ADC0    0
#define       ADC1    1
#defineLOW0
#define       MEDIUM1
#defineHIGH2

// Step up gain when amplitude of FILTERED signal drops below AMP_LO.
// Assuming 8.000x gain, the threshold may not be set higher than:
//
//  AMP_LO(max) = 255 * [(1023/2) / 8] = 16304d = 3FB0h
//
// Measurement results indicate 1% accuracy can be reached at amplitudes as
// low as 25, at unity power factor. Leaving some headroom for 0.5 power
// factor measurements, the recommended minimum is:
//
//  AMP_LO(min)  =  255*50  =  approx
3200h #defineAMP_LO0x3200

// Step down gain when UNCONDITIONED data is below SAT_LO or above SAT_HI
#defineSAT_LO0x0007
#defineSAT_HI0x03F8

// Wait GAIN_HOLD samples after range switch before allowing new switch
#defineGAIN_HOLD480

// Starting current in amps: this should be no more than 0.002 x base cu r-
rent
#defineI_MIN0.002

// Power threshold in watts: disable tamper logic when active power below
this
#defineP_MIN1.000

// Constant offset, which is added to sampled data. Should not be more than
// 1/2 LSB*255, typically OFFSET = 80h. Else transfer funtion may grow non-
// linear (especially at power factors other than 1).
#defineOFFSET0x80

// Flags
#defineDISPLAY0x01
#defineGROGGY0x02
#defineKEY_PRESSED0x04
#defineCYCLE_FULL0x08
#defineMOREGAIN00x10
#defineLESSGAIN00x20
#defineMOREGAIN10x40
#defineLESSGAIN10x80

// Number of samples that will be accumulated for measurements. Since
measure-
// ments are based on a fixed time window, the accumulation cycle should be
// such that it fits an integer number of mains cycles. Otherwise,
measurement
// results will fluctuate and create short-term variations. Even so, the
// effects can be completely removed by means of averaging the measurement
// results. No harm done in the long run, but may look strange and gives a
// false impression of poor accuracy.
```

```
//
// For compliancy with both 50Hz and 60Hz environments, the cycle length
// should be chosen such, that it can fit an integer number of both 50Hz
and
// 60Hz signals. For example, cycle lengths of 200ms multiples are fine.
// Some suitable cycle lengths are as follows:
//
//     XTAL  |    ADC  | ADCCLK  |  Sampling  | S.R./Ch | Cycle   |     50Hz |
60Hz
//    [MHz]  |  Presc  |   [Hz]  | Rate [Hz]  |    [Hz] | Length  |   Cycles |
Cycles
//    ------+-------+--------+-----------+---------+--------+---------+-----
---
//    3.580  |    128  | 27965   | 2151.169   |  717.06 |   N*72  | N*5.021 |
N*6.025
//    3.689  |    128  | 28800   | 2215.385   |  738.46 |   N*74  | N*5.010 |
N*6.012
//    4.000  |    128  | 31250   | 2403.846   |  801.28 |   N*80  | N*4.999 |
N*5.999
//     -"-   |    -"-  |  -"-    |     -"-    |    -"-  |     80  |  4.9920 |
5.9904
//     -"-   |    -"-  |  -"-    |     -"-    |    -"-  |    401  | 25.0225 |
30.0270
//    4.096  |    128  | 32000   |  2461.538  |  820.51 |   N*82  | N*5.000 |
N*6.000
//    4.608  |    128  | 36000   | 2769.231   |  923.08 |   N*92  | N*4.983 |
N*5.980
#defineNMAX    401
#defineNORM1.0/NMAX

// This is the length of pulses DPP and DPN, measured in sampling periods.
// For example, DP_ON=241 at sampling rate 2403Hz results in pulse lengths
// of (241-1)/2403 = 0.100s.
#defineDP_ON241

// Polynome used in CRC calculations
#define CRC_POLYNOME0x8005
```



J0
AC IN
BRIDGE 1
IC1
7805
Vin
+5V
GND
1000uF
0.1uF
100uF
R
470
D5
LED
J1
5V OUT
JP0
4 HEADER
VCC
GND
R1
110kΩ
CT
L3
L4
2mA/2mA
R2
66Ω
R3
1K
R4
R5
R6
C6
C7
C8
103
VIN+
VIN-
5A/2.5mA
R7
30Ω
R8
R9
R10
R11
C9
C10
C11
IIN+
IIN-
L1
L2
Y2
4.096M
CS5460
XOUT
XIN
CPUCLK
SDI
VD+
EDIR
DGND
EOUT
SCLK
INT
SDO
RESET
NC
PFMON
VREFOUT
REFIN
VA+
VA-
C1
C2
30P
Y1
11.0592MHz
C4
104
MCU模块
U4
AT89S52
RST
RXD/P3.0
TXD/P3.1
XTAL1
XTAL2
VSS
ALE
PSEN
EA
R0
BLK
BLA
RSE T
PSB
RS
R/W
E
VO
VDD
CS
SDI
SCLK
液晶显示
S1
S2
S3
S4
SW-PB
P2.4
P2.5
P2.6
P2.7
R21
R22
R23
R24
10K
RST
R3
C3
复位电路
J5
串口
CART
DB9-2
DB9-3
U2
MAX232
C1+
C1-
C2+
C2-
V+
V-
T2out
R2in
R2out
T1out
R1in
R1out
T1in
T2in
C5
1uF
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