Evaluation Board for the SA9903B Energy Metering IC

PM9903BPE

FEATURES

- Designed to be used together with accompanying software as fully functional single phase trivector meter.
- Operation better than class 1 operation for active and class 2 for reactive energy.
- On board power supply.
- Two on-board LED's for active and reactive pulse output.
- Single Phase 2 wire configuration, 230V 80A (Imax).
- On-board LCD.
- Current sensing via on-board shunt or optional CT.
- Isolated connection to PC parallel port.
- Easy accessible test pins.
- Micro-controller plug-in support
- Micro-controller / PC operation

DESCRIPTION

This Application Note describes the PM9903BPE evaluation board and together with the SA9903B data sheet provides a complete evaluation platform. The SA9903B is an accurate bi-directional power / energy measurement IC with serial (SPI) interface measuring active as well as reactive power / energy, RMS voltage and frequency. More detailed information specific to the SA9903B can be found in its datasheet.

The PM9903BPE module is designed for single-phase two-wire applications. The mains voltages easily connect to the module by way of a Molex connector (SK1).Anon-board shunt resistor measures the current, while provision has been made to insert a current transformer in place of the shunt. A simple transformer power supply supplies the energy metering IC with power. The 78L05 regulator is used to generate a 5 V supply voltage for the device and on-board opto-couplers. Provision has been made to connect an external 5V power supply to drive the isolated opto-coupler.

The SA9903B forms the energy/power metering front-end of the module and connects to the SPI bus. Sharing the SPI bus is the SA8807A LCD driver which is capable of driving 96 segments on a 4 back plane LCD.

The PM9903BPE evaluation board is configured and calibrated via the parallel port of a PC. The data interface between the evaluation board and the PC is fully isolated.

The PM9903BPE module can easily be connected to a micro-controller. The SAMES micro-controller board connects to the evaluation module by means of the SPI and JP3 connectors thereby creating a complete power meter without the PC interface. Physically the micro-controller board plugs into the evaluation module with its opto-coupler facing the mains connector (SK1). It shares the SPI bus with the SA8807A onboard LCD controller.

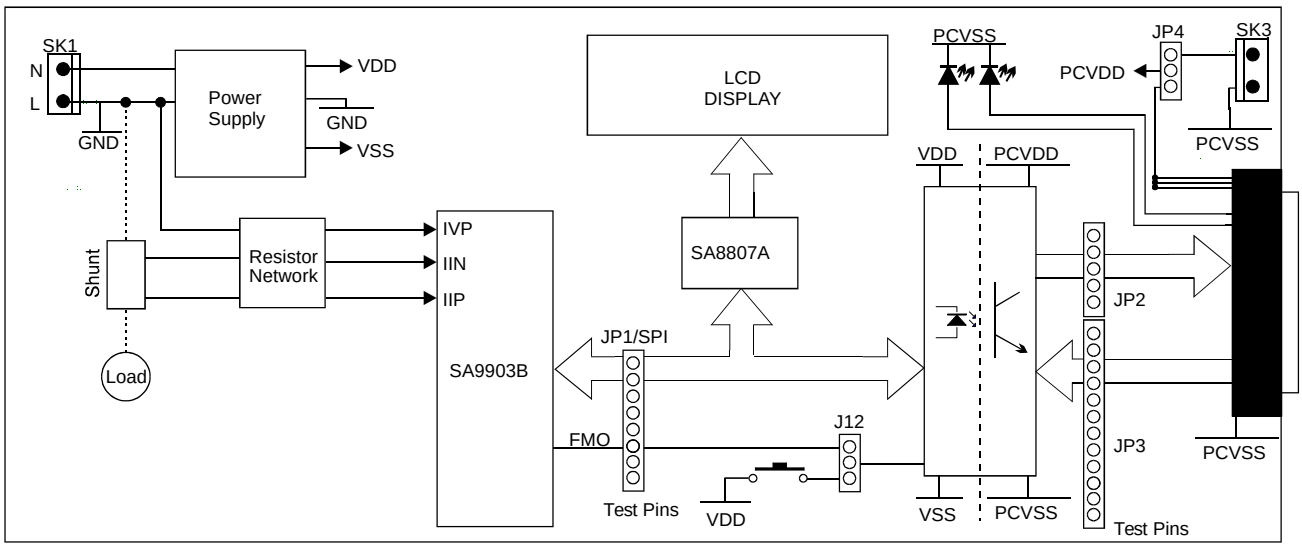


Figure 1: Block diagram

JUMPER SETTINGS

Power supply jumpers

The power supply jumpers are used to disconnect the on-board power supply, allowing the metering section of the circuit to be powered from an external power supply if required.

Jumper	Description
J4	Connects V_{DD} to the metering circuitry. Default closed
J5	Connects V_{SS} to the metering circuitry. Default closed
J6	GND connection point.

Shunt / CT selection Jumper

The PCB makes provision for the use of a current transformer in place of the shunt. If required the shunt can be removed and a current transformer inserted. In this case J7 must be closed and the applicable CT termination resistor (R26) inserted.

Jumper	Shunt	CT
J7	OPEN R26 not required	Closed R26 inserted

Communication jumpers

Jumpers J8 to J11 connect pull up resistors to the SPI inputs of the SA9903B. The pull up resistors are required by the open drain outputs of the HCPL2631 opto-couplers. If a PC is used with the PM9903BPE module the jumpers must be closed, and can be left closed in the case of the SAMES micro-controller board. This board is capable of driving the SPI bus in this state. Default Closed.

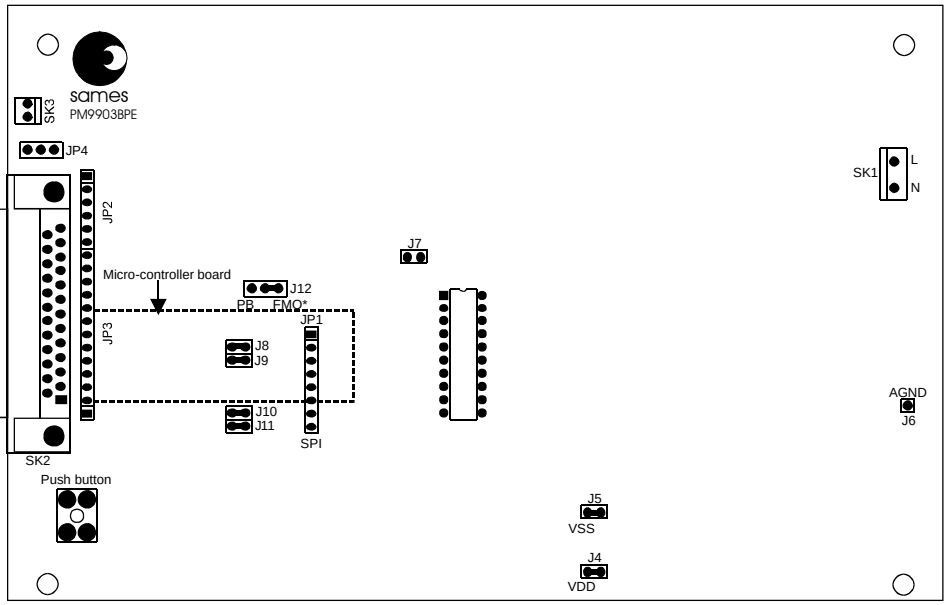
An additional output from the module is made available to the parallel port of the PC. The output can be selected to be the SA9903B's FMO output or it can be selected to be the modules push button output.

Jumper	Description
J12	PB (left connection) - Connects the push button output through a opto-coupler to pin 13 of the parallel port FMO (right connection) - Connects pin 15 of the SA9903B through a opto-coupler to pin 13 of the parallel port

Parallel Port power supply jumper

Jumper JP4 is used to select the power source for the opto-coupler U7. Power can be taken from the PC's parallel port or from an external 5 volt supply via SK3.

Jumper	Description
JP4	Left connection - Power for U7 is taken from the PC's parallel port (pins 1, 14,16,17) Right connection - Connects U7 to SK3. An external power supply can be connected to SK3 to power U7.



** On some pcb's this may be labled as PB/F150, however FMO and F150 is the same connection.*

Figure 2: Jumper positions

CONNECTOR DESCRIPTION

Jumper	Description
SK1	Connects the single phase supply to the module.
SK2	Female BD25pin connects the evaluation board to the PC parallel port by a 1 to 1 cable. The module is isolated from the PC by the opto-couplers.
SK3	5V supply to U7 opto coupler
JP1	This header strip can be used for measuring the I/O pins of the SA9903B and SA8807A. Note that this connector is on the same potential as the SA9903B. Provision is made for V_{DD} and V_{SS} so that a board with a micro controller can be easily fitted without any additional wiring. Signals available on this connector are:

Pin number	Signal	Sa9903 (U1)	SA8807 (U2)
1	V_{DD}	Pin 8	Pin 13
2	V_{SS}	Pin 14	Pin 26
3	FMO	Pin 15	NC
4	SCK	Pin 12	Pin 18
5	CS	Pin 18	NC
6	MISO	Pin 13	Pin 20
7	MOSI	Pin 17	Pin 19
8	CE	NC	Pin 21

MISO - Master In Slave Out
MOSI - Master Out Slave In

SETTING UP THE PM9903BPEMODULE

Figure 3 below shows a typical setup for the PM9903BPE evaluation module. The mains voltage is connected directly to SK1 and the live current is wired through the on-board shunt. An external power supply can be connected to SK3 should the PC's parallel port not be able to source enough current for the module's opto-couplers.

The PM9903BPE evaluation module is setup by default for 230V/80A operation.

When the hardware settings have been verified the user has the choice of using the micro-controller board or a PC to evaluate the SA9903B further. Please note when using the PC the micro-controller board should be unplugged to prevent a SPI bus contention, since the PC and micro-controller would be attempting to drive the bus simultaneously.

Micro-controller board

Once the board has been plugged into the evaluation module no further action is required, just apply power.

PC

After removing the micro-controller board the evaluation board can be connected to the PC's parallel port using a 1 to 1 parallel cable (not supplied). Once the evaluation board has been connected to the PC and powered up, the supplied software can be launched. Refer to the next section for the software installation and setup details.

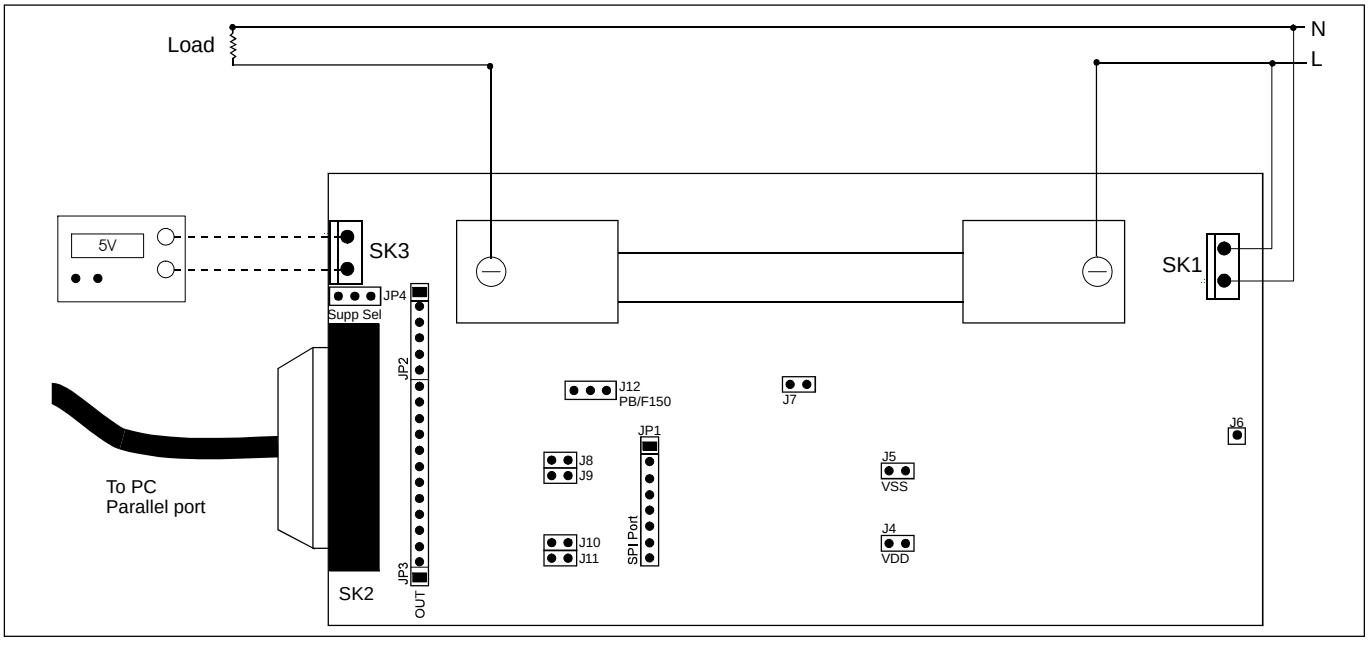


Figure 3: PM9903BPE setup and connection

PM9903BPE EVALUATION SOFTWARE

Software for the SA9903BPE module is designed to communicate with the SA9903BPE module via the PC's parallel port. There are two versions, one for Windows 9x/NT/XP and one for Dos. The source code (C++ Builder for the Windows version and Borland C++ for the Dos version) is also included.

File Description:Windows software

The source code is contained in the "Windows Source.zip" file. The most important files are:

MainUnit.cpp
This file contains the functions to write/read to the SA9903 registers, write to the LCD, meter calculations and pulse generation.

AdvancedUnit.cpp
This file contains the functions for reading the parameters from the advanced settings form (meter pulse constant, rated voltage, etc)

Common.h
All the constants.

File Description: Dos software

The following files are included on the floppy disk:

9903mtr.c
This file contains the source for the functions that read the SA9903 registers, store these values in integration registers, check for any overflow and generate the corresponding energy pulse for the PM9903BPE on-board LED's. The software does not make use of timers and relies on counting the software loops to generate reasonable delays for the LED outputs.

pc_spi.c
This file contains the source for all the SPI interface routines which are used to communicate between the PM9903BPE module and the PC's parallel port.

pc_lcd.c
This file contains the source for all the functions relating to the SA8807 LCD driver IC, as well as other functions to switch on the LCD display icons.

9903mtr.exe
This is the executable file.

Running theWindows software

The program has to be installed first. Run the "SETUP.EXE" file and follow the on-screen instructions. After installation, the program can be launched from the windows menu (Start -> Programs -> PM990x -> PM990x).

For instructions on using the program, see the programs help file (PM990x.hlp)

Running the Dos software

The program is executed by running the 9903mtr.exe file with the following arguments:
9903mtr.exe 1 / s

The first parameter specifies the LPT port address to use where 1= 0x378 (LPT1) and 2 = 0x278 (LPT2).

The optional second parameter invokes the meter-setup menu. On this menu the user enters the module's rated conditions, i.e. $V_{nominal}$, I_{max} and required pulse rate. This enables the module to be used at rated conditions other than the default. The meter-setup menu is invoked automatically if the software doesn't find a calibration file in the root directory. Otherwise the user can force a meter setup by using the /s option on the command line.

Further detail can be found in the readme. 1st file in the DOS directory on the supplied disk.

Generating pulses proportional to the measured energy

Figure 4 is a flow diagram showing how to generate pulses proportional to energy measured by the SA9903B. The speed of execution is not critical, although it will influence the resolution of the pulses that is generated.

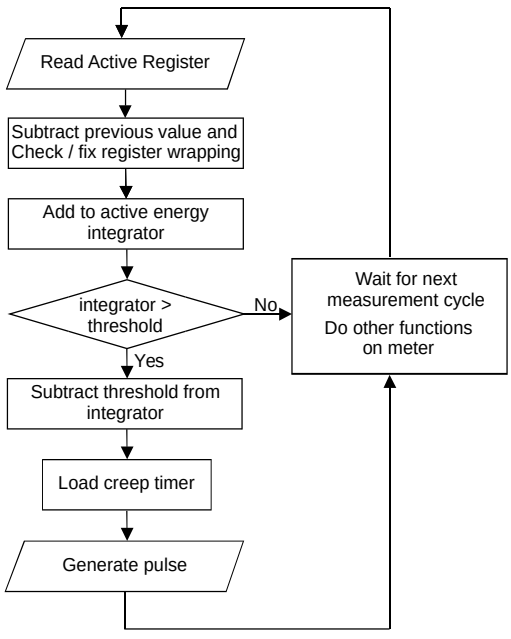


Figure 4: Pulse flow diagram

It is recommended that the flow diagram be implemented together with a timer interrupt used for the creep timing.

Threshold and pulse rates

The active and reactive registers on the SA9903B increment at a rate of 320 000 counts per second at rated metering conditions for a sine wave. A single count of the active register corresponds to an amount of energy expressed in Watt seconds (Ws).
Energy per count is (Ws):
$Epc = V_{nom} \times I_{max} / 320\,000$

where:
Vnom is the mains voltage and correspond to 14µA in the voltage inputs of the SA9903B.

Imax is the maximum mains current to be measured and correspond to 16µA on the current inputs of the SA9903B.

The pulse rate required for a meter is usually expressed in pulses/kWh. A single pulse on the LED is mostly a fraction of a kWh and is converted to energy inWs/pulse
Energy per LED pulse is (Ws/pulse):
Epp energy = 1000 x 3600 / Mpr

where:
Epp is energy per LED pulse
Mpr is themeterpulse rate ormeterconstant in pulses/kWh

The threshold is calculated by dividing the energy represented by a LED pulse by the energy per register count.

Active energy threshold = Epp / Epc

The threshold is thus the amount of energy to be measured (accumulated / integrated) by the meter before a LED pulse is generated.

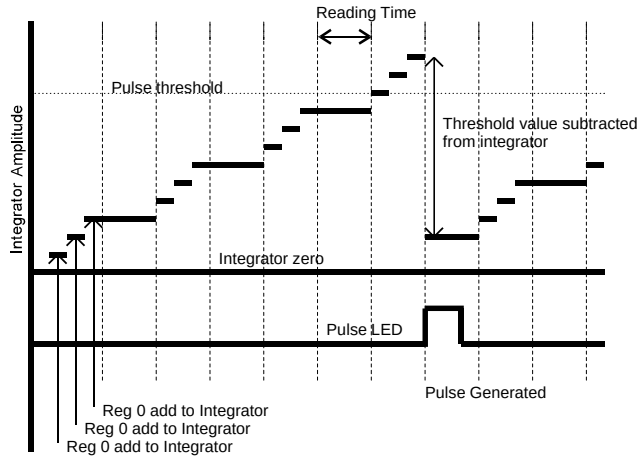


Figure 5: Implementation of an overflow integrator

Meter creep current

For the SA9903B meter creep must be taken care of in software. From the explanation above on how to generate pulses, the meter must also be prevented from pulsing in cases where the energy measured is less than the creep threshold as per the meter specification. The creep current is defined as the limit for measured energy, any energy less than the creep threshold is discarded, and energy above the creep threshold is measured.

The simplest way to implement the creep threshold is to relate it to the time between meter pulses. If the time between pulses is more than the limit, the energy accumulator is cleared.

Pulse rate of meter at rated conditions (Hz):
$Rf = (V_{nom} \times I_{max} / 1000) \times (Mpr / 3600)$

Where:
V_{nom} is the mains voltage and correspond to 14µA in the voltage inputs.

I_{max} is the maximum mains current to be measured and correspond to 16µA on the current inputs of the device.

Mpr is themeterpulse rate in pulses/kWh.

Creep threshold time (s):
$Ct = 1/(Cc / I_{max}) \times Rf$

where:
Cc is the specified creep current; energy below this value is discarded.

I_{max} is the maximum mains current to be measured and correspond to 16µA on the current inputs of the device.

Rf is the rated current frequency.

The flow diagram (figure 6) for the timer interrupt shows how the time between pulses is measured, if the time since the last pulse is more than the time measured, the integrator is reset and a new count down is started.

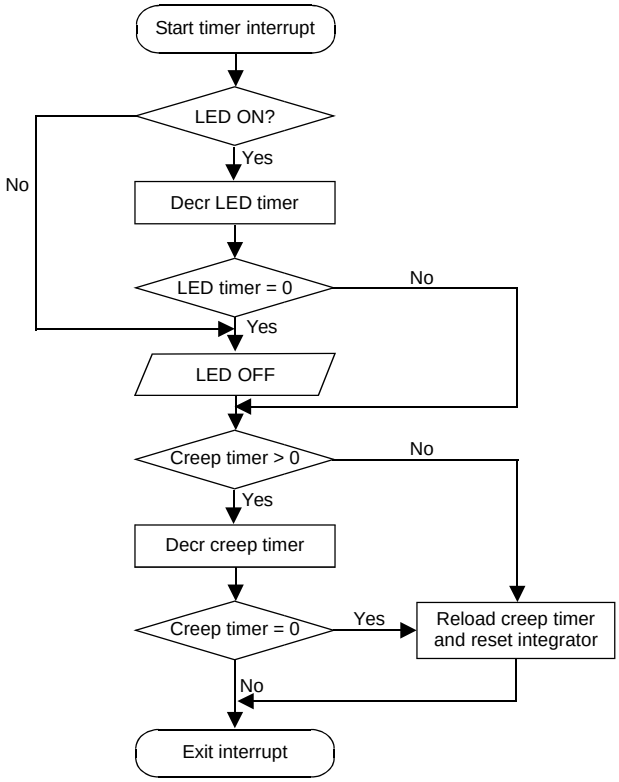


Figure 6: Interrupt flow diagram

THE MICRO-CONTROLLER BOARD

OVERVIEW

This section describes the plug-in micro-controller board and should be read in conjunction with the evaluation software section, where basic metering software is described. The micro-controller's software was developed according to this section. The board plugs into the evaluation module as described earlier in this application note.

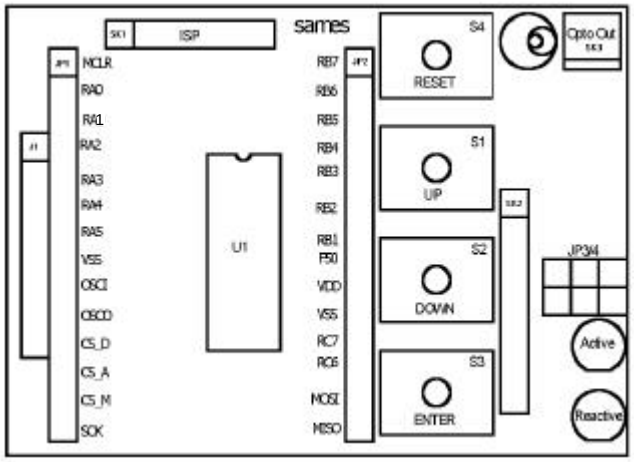


Figure 7: Micro-controller board

Hardware

The schematic is presented in Figure 18. As can be seen the major elements are:

- micro-controller,
- eeprom,
- keys,
- rate LEDs / opto-isolated rate pulse output
- andmiscellaneous connectors.

Micro-controller

A PIC 16F876-20/so is used to generate the rate pulses, in this application the micro uses a 20 MHz crystal (X1). This device has 8kB Flash ROM (program memory) and 368 Byte RAM (data memory). Detail information on the device can be obtained in the appropriate MICROCHIP datasheet.

EEPROM

A 93C46 EEPROM provides storage for non-volatile data, such as calibration factors. This device has 1 kB space available or stated differently 128 x 8bit words.

Keys

Four keys are provided of which one is connected to the micro-controller's reset pin. The other three are available to implement an HMI (Human Machine Interface) in the firmware; they're labelled Up/Down and Enter on the printed circuit board.

Rate outputs

Two LEDs are provided for active and re-active energy respectively. These pulse outputs can be coupled to an opto-coupler via JP3/4 providing an output for external usage. This output-pulse selection is accomplished with a jumper on JP3/4 as follows:

- Jumper on board's outside edge = active
- Jumper on board's centre pins = re-active
- Jumper on board's inside edge = not used

Miscellaneous

Connectors JP1 and JP2 are provided to ease debugging during code development, all relevant signals are available. J1 in conjunction with SK2 are the two plug-in points to the evaluation module, where SK2 is the SPI connector and J1 merely a stabilising holder. The micro-controller is programmed via SK1 using the controller's ICSP (in circuit serial programming) capability, as described in the relevant MICROCHIP datasheet. If the intention is to program the board

from MICROCHIP's PICSTART-programmer a buffer needs to be inserted in the V_{DD} line to boost the programmer's output capability. An example of such a buffer is shown in Figure 8.

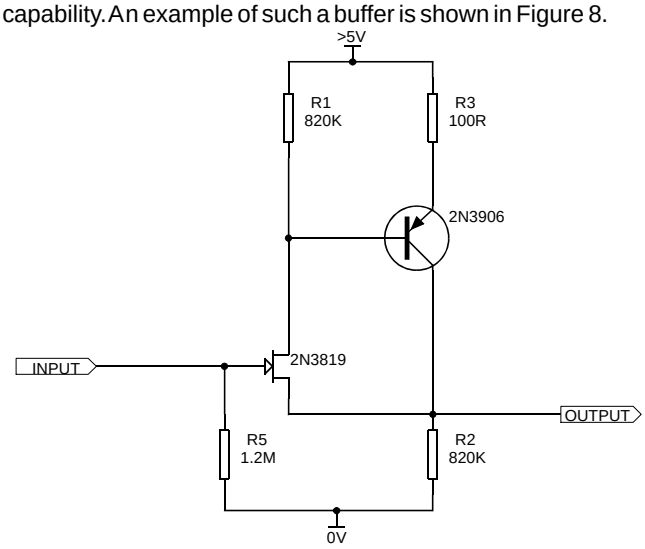


Figure 8: Typical buffer circuit

Firmware

The micro-controller's code was created according to the guidelines set out in the evaluation software section. It is presented as a kick-start to experimentation with the micro-controller module and as such shouldn't be seen as the only possible implementation. The code was generated using Hi-Tech PIC C (v8.00PL1); the demo version on their www site (www.htsoft.com) is sufficient for experimentation. The program flow is presented in Figure 9.

SPI

The 16F876's SPI hardware is used to read the SA9903B's registers, using normal byte wide protocol. All registers are read after receiving a zero-crossing (FMO) interrupt from the SA9903B. The CE signal enables the SPI for the display driver and the CS signal enables the SPI for the SA9903B.

Rate LEDs / opto-outputs

The 10ms pulse widths on these outputs are derived from a timer interrupt.

Creep

If the time between two successive pulses is greater than a predefined maximum, the respective energy accumulator is cleared. The simplest method of deciding what the predefined value should be is to measure the time between two pulses at the lowest permissible load current, this is then expressed i.t.o basic timer ticks.

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User Interface

A simple interface has been implemented using two of the three available keys. The Enter Key toggles display of consumed kWh and kVARh units. The Down Key display of RMS voltage and frequency data.

The LCD is updated each second based on the last 'key-press' value.

Memory Usage

ROM:

3452 words or 42% of the total capacity

RAM:

$Bank_0$	78 bytes	
$Bank_1$	77 bytes	
$Bank_2$	--	
$Bank_3$	--	or 39% of the total capacity

Please refer to the readme. 1st file for any updated information not contained in this application note. The mentioned file is part of the source code that accompanies this module.

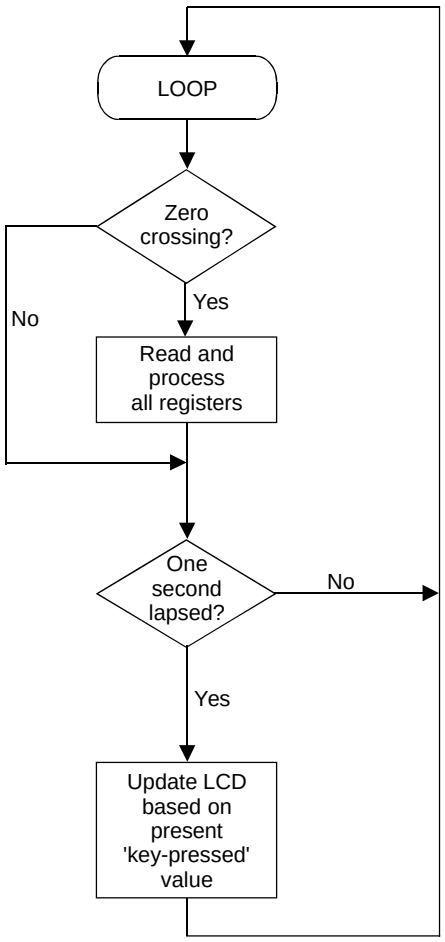


Figure 9: Program flow

CIRCUIT DESCRIPTION

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 230V/80A with precision better than Class 1.

The most important external components for the SA9903B integrated circuit are the current sense resistors, the voltage sense resistors and the bias setting resistor. The resistors used in the metering section are of the same type to minimize any temperature effects.

Bias Resistor

Pin VREF (SA9903B pin 3) is connected to Vss via R9 which determines the on chip bias current. With R9=24kΩ optimum conditions are set. VREF does not require any additional circuitry.

CT Termination Resistor (when using a CT)

The voltage drop across the CT termination resistors R26 should be at least 20mV at rated current (Imax). The termination resistor should be less than the CT's DC resistance. Be sure to insert J7 after inserting R26.

For 80Ameter R26 = 2.7Ω
When R1 = R2 = I_L / 16µA / 2500 x RSH / 2
= 80/16µA / 2500 x 2.7Ω
= 2K7

Current Sense Resistors (when using a shunt)

Referring to figure 10 the resistors R1 and R2 define the current level into the SA9903B's current sense inputs (IIP and IIN). The resistor values are selected for an input current of 16µA into the current inputs at rated conditions.

According to equation described in the Current Sense inputs section of the datasheet:

R1 = R2 = (I_L / 16µA) x RSH / 2
= 80A / 16µA x 625µΩ / 2
= 1K56
1.6K is selected

where:

I = Line current or if a CT is used I = line current / CTRatio
RSH = shunt resistance (625µΩ) or if a CT is used RSH = CT termination resistor value.

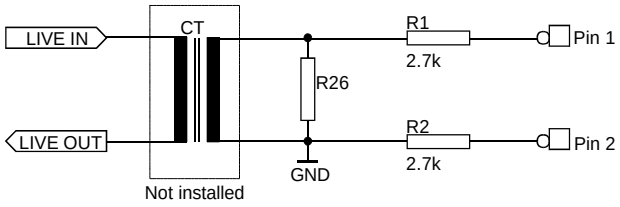


Figure 10: Current input configuration

Voltage Divider

Referring to figure 11 the connections for the voltage sense input for one phase is shown. The current into the A/D converter (IVP) is set 14µA$_{RMS}$ at nominal mains voltage. This voltage sense input saturates at approximately 17µA$_{RMS}$. A nominal voltage current of 14µA allows for 20% over driving. Each phase voltage is divided down by a voltage divider to 14V. The current into the voltage sense input is set at 14µA via a 1MΩ resistor.

The following equation is used to calculate the 14V voltage drop:
RA=R22+R23+R24
RB = R8 || R13
Combining the two equations gives:
(RA + RB) / 230V = RB / 14V
A 24kΩ resistor is chosen for R13 and a 1MΩ resistor is used for R8.
Substituting these values result in:
RB = 23.44kΩ
RA=RBx(230V/14V-1)
RA=361.6kΩ

Resistor values of R22, R23 and R24 are chosen to be 120kΩ.

If a CT is used capacitors C500 / C501 can be used to compensate for phase shifts between the SA9903's voltage sense inputs and current sense inputs. The value of the phase shift compensation capacitors are calculated as follows, assuming a phase shift of 0.18 degrees.

C = 1 / (2 x π xMainsfrequency x R8 x tan (Phase shift angle))
C = 1 / (2 x π x 50Hz x 1MΩ tan (0.18 degrees))
C = 1.013µF

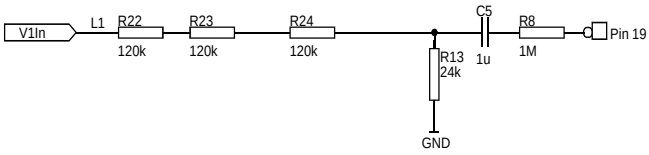


Figure 11: Mains voltage divider

Power Supply

The PM9903BPE module uses a transformer based power supply. The maximum current that can be drawn by the circuit is approximately 100mA. The normal operating current of the module is closer to 30mA. An 78L05 voltage regulator is used to regulate the voltage from the transformer. Two resistors (R500 and R501) generate the analog ground voltage for the SA9903B. The SA9903B operates between 0V and 5V with the GND pin connected tomid-rail.

PCB DESIGN

The PM9903BPE evaluation module represents a Class 1 meter and is designed to demonstrate the functionality and performance of the SA9903B metering integrated circuits. The SA9903B is mainly the analog front end of a meter. The SA9903B measures the energy, voltage and frequency which aremadeavailable via SPI to an external controller / PC.When themeter's PCB is designed, it should be remembered that the SA9903B inputs are analog and special care need to be taken with the power supply and signal routing to the SA9903B.

Protection

The SA9903B should be protected from the measuring environment. This is achieved by using resistor dividers to scale all the SA9903B's input signals. MOV's Z1 together with resistor R83 protects the power supply transformer as well as the voltage sense inputs. The current setting resistors on the current sense inputs attenuates any common mode and asymmetrical transients.

Component placement

All the resistors on the SA9903B's current sense inputs should be placed as close as possible to the SA9903B. This eliminates the possibility of any stray signals coupling into the input signals.

Ground Plane

The GND pin of the SA9903B is connected to the neutral phase, which is halfway between V_{DD} and V_{SS}. Note that supply bypass capacitors C1 and C2 are positioned as close as possible to the supply pins of the SA9903B, and is connected to a solid ground plane. Capacitor C6 is also positioned as close as possible to the supply pins of the SA9903B for proper supply bypassing.

Power Supply routing and de-coupling

The 5V supply is de-coupled and routed directly to the power pins of the SA9903B by means of capacitor C506. Care was taken not to have current flowing in the node that connects the voltage reference resistor to V_{SS} as it may introduce power supply noise on the voltage reference circuit.

Signal Routing

The signal routing is done in such a manner that any signal coupling in to the measured signal will be a common mode noise signal and is subsequently rejected. Care should be taken that the signals to the SA9903B not be influenced by other sources such as electric fields from transformers etc.

THE SA8807A LCD DRIVER

OVERVIEW

The SAMES SA8807A Liquid Crystal Display (LCD) driver is capable of driving up to 96 LCD segments and is designed for displays having 3 or 4 track multiplexed back planes. The SA8807A includes an on-chip oscillator and needs only a single external capacitor. Communication to the SA8807A is via the Serial Peripheral Interface (SPI) which is shared with the SA9903B.

This LCD driver is ideal for any micro-controller based system requiring a liquid crystal display of up to 12 seven-segment digits.

USING THE SA8807A

Oscillator

The SA8807A includes an on-chip oscillator that is controlled by a single external capacitor. Adjusting the capacitor value will change operating frequency of the SA8807A. The back plane multiplexing is a function of the SA8807A operating frequency. It is thus important to select the frequency high enough that the multiplexing of the display is not noticeable, but still within limits of the LCD display reaction time.

f =7µF x 0.1Hz / C
f = Required oscillator frequency
f / 8 = back planemultiplex rate for a 4 back plane display

SPI Interface

The SA8807A shares the SPI interface with the SA9903B and connects directly to the opto-couplers on the PM9903BPE evaluation board.

Commands

The demonstration software uses a buffer in memory on the PC to generate the complete display. The buffer is dumped to the LCD driver device in one go. The data passed to the driver IC is formatted with a starting address followed by the data for all segments. The first 8 bits is interpreted as address byte and the rest of the data is sequentially passed as data bytes. The address counter on the driver IC is incremented every 8 clocks. The procedure is repeated until all of the LCD memory is filled up.

Address

The address of the data is set up in the followingmanner

To write to the device the following address is passed:
1 0 A5A4A3A2A1A0

Data

Data to the device is passed with MSB first
D7 D6 D5 D4 D3 D2 D1 D0
Were D7 and D3 map to pin VR[3] of driver and COM4 of LCD
Were D6 and D2 map to pin VR[2] of driver and COM3 of LCD
Were D5 and D1 map to pin VR[1] of driver and COM2 of LCD
Were D4 and D0 map to pin VR[0] of driver and COM1 of LCD
See SA8807Adatasheet formoreinformation.

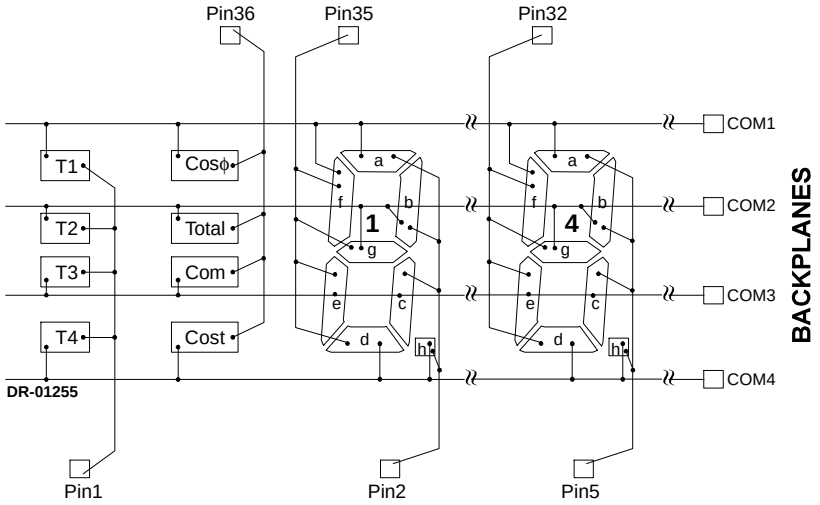


Figure 12: Mapping of a single character

Address	5		4		3		2		1		0	
LCD Pin	**30**	**7**	**32**	**5**	**33**	**4**	**34**	**3**	**35**	**2**	**36**	**1**
COM1, 17	5f	5a	4f	4a	3f	3a	2f	2a	1f	1a	Cosϕ	T1
COM2, 18	5g	5b	4g	4b	3g	3b	2g	2b	1g	1b	Total	T2
COM3, 19	5e	5c	4e	4c	3e	3c	2e	2c	1e	1c	Com	T3
COM4, 20	5d	5h	4d	4h	3d	3h	2d	2h	1d	1h	Cost	T4

Table 1: LCD display memory map

Address	11		10		9		8		7		6	
LCD Pin	**23**		**21**	**16**	**22**	**15**	**24**	**13**	**26**	**11**	**28**	**9**
COM1, 17	Blank	Blank	k1	k2	% Error	V	8f	8a	7f	7a	6f	6a
COM2, 18	Blank	Blank	Hz	W	imp/KWh	A	8g	8b	7g	7b	6g	6b
COM3, 19	Blank	Blank	~ 1	s	Wh/imp	r	8e	8c	7e	7c	6e	6c
COM4, 20	T1, T2, T3, T4	Total	~ 2	h	~ 3	h	8d	8h	7d	7h	6d	6h

Table 2: LCD display memory map (continued)

THE LIQUID CRYSTAL DISPLAY

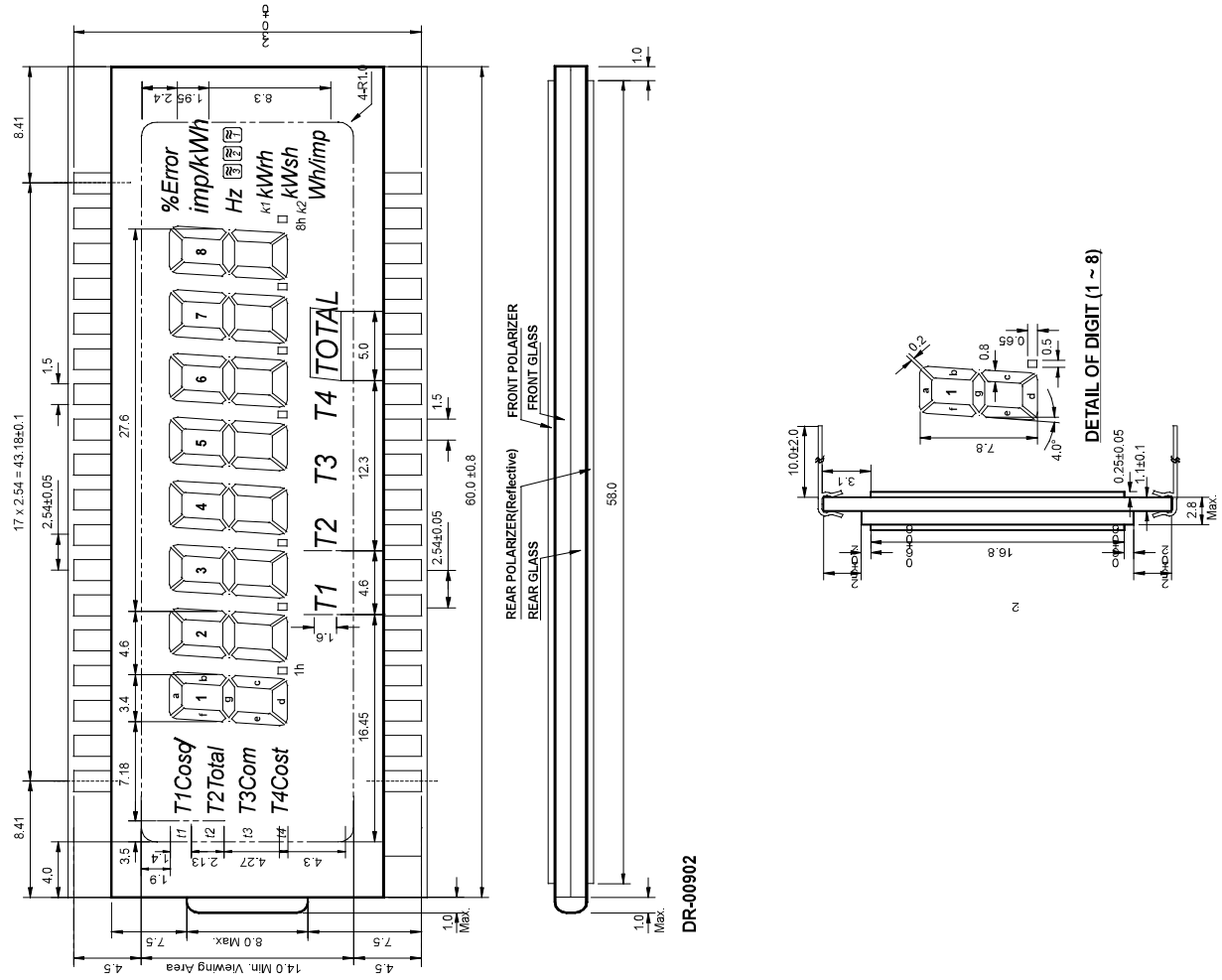


Figure 13: All the Icons and Dimensions of LCD

Pin	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	23	23
COM1	cosϕ	1f	2f	3f	4f		5f		6f		7f		8f		%Error	k1		
COM2	Total	1g	2g	3g	4g		5g		6g		7g		8g		imp/KWh	Hz		
COM3	Com	1e	2e	3e	4e		5e		6e		7e		8e		Wh/imp	~ 1	COM3	
COM4	Cost	1d	2d	3d	4d	T1	5d	T2	6d	T3	7d	T4	8d	Total	~ 3	~ 2		COM4

Table 3 : Mapping of display

Pin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
COM1	T1	1a	2a	3a	4a		5a		6a		7a		8a		V	k2	COM1	
COM2	T2	1b	2b	3b	4b		5b		6b		7b		8b		A	W		COM2
COM3	T3	1c	2c	3c	4c		5c		6c		7c		8c		r	s		
COM4	T4	1h	2h	3h		4h		5h		6h		7h		8h	h	h		

Table 4 : Mapping of display (continued)

SCHEMATIC

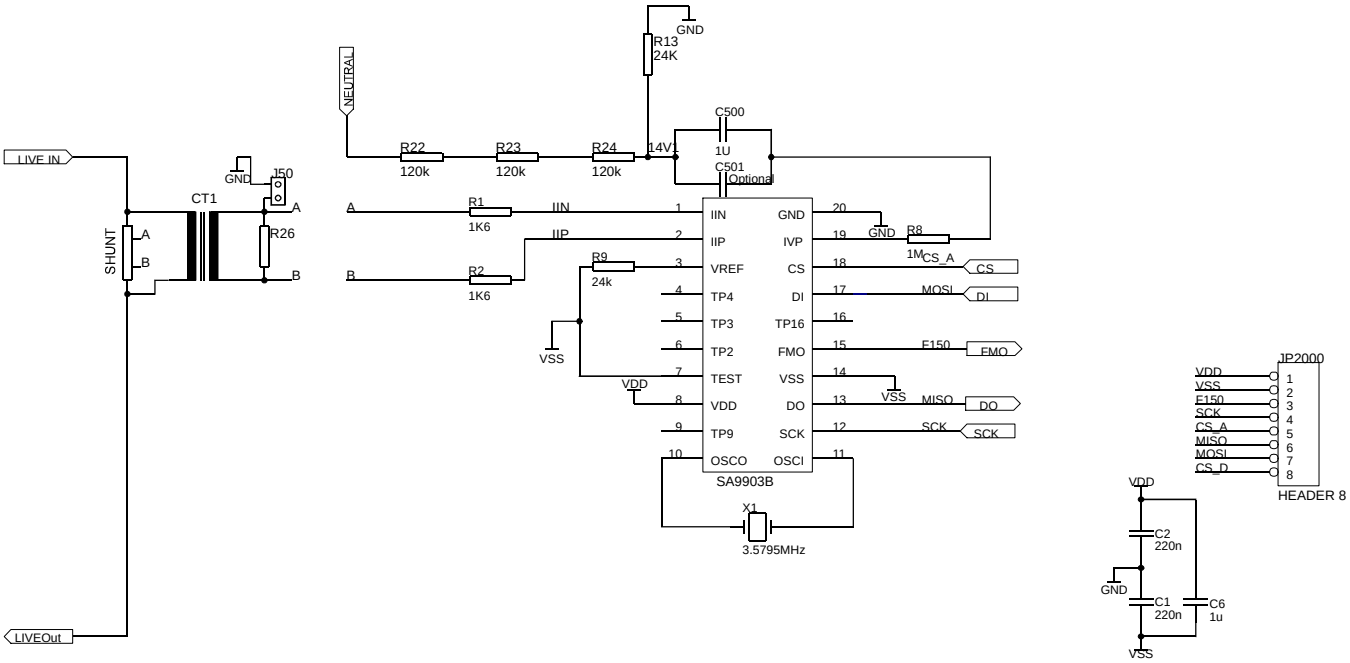


Figure 14 : Schematic diagram of metering section

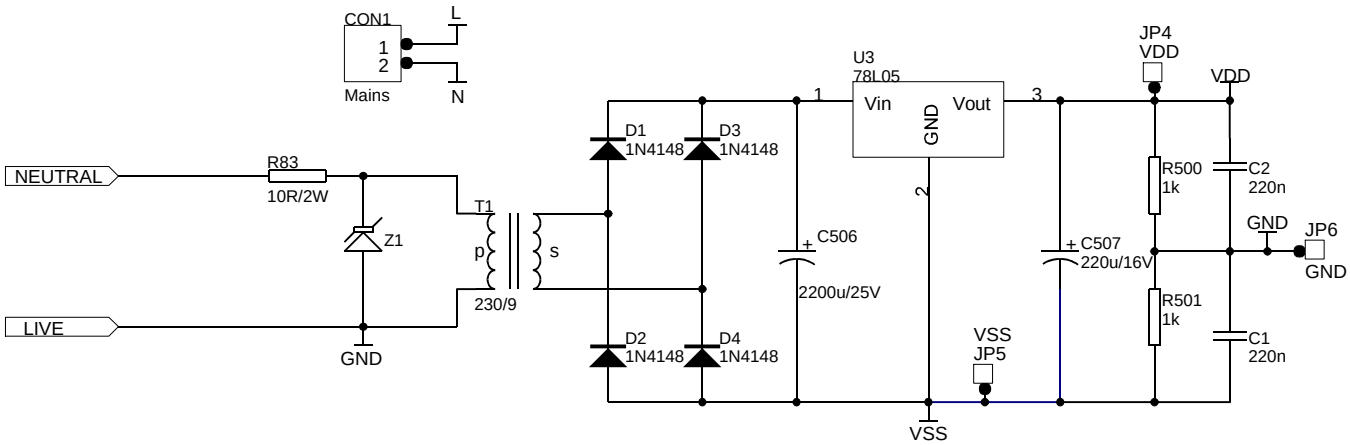


Figure 15: Schematic diagram of power supply

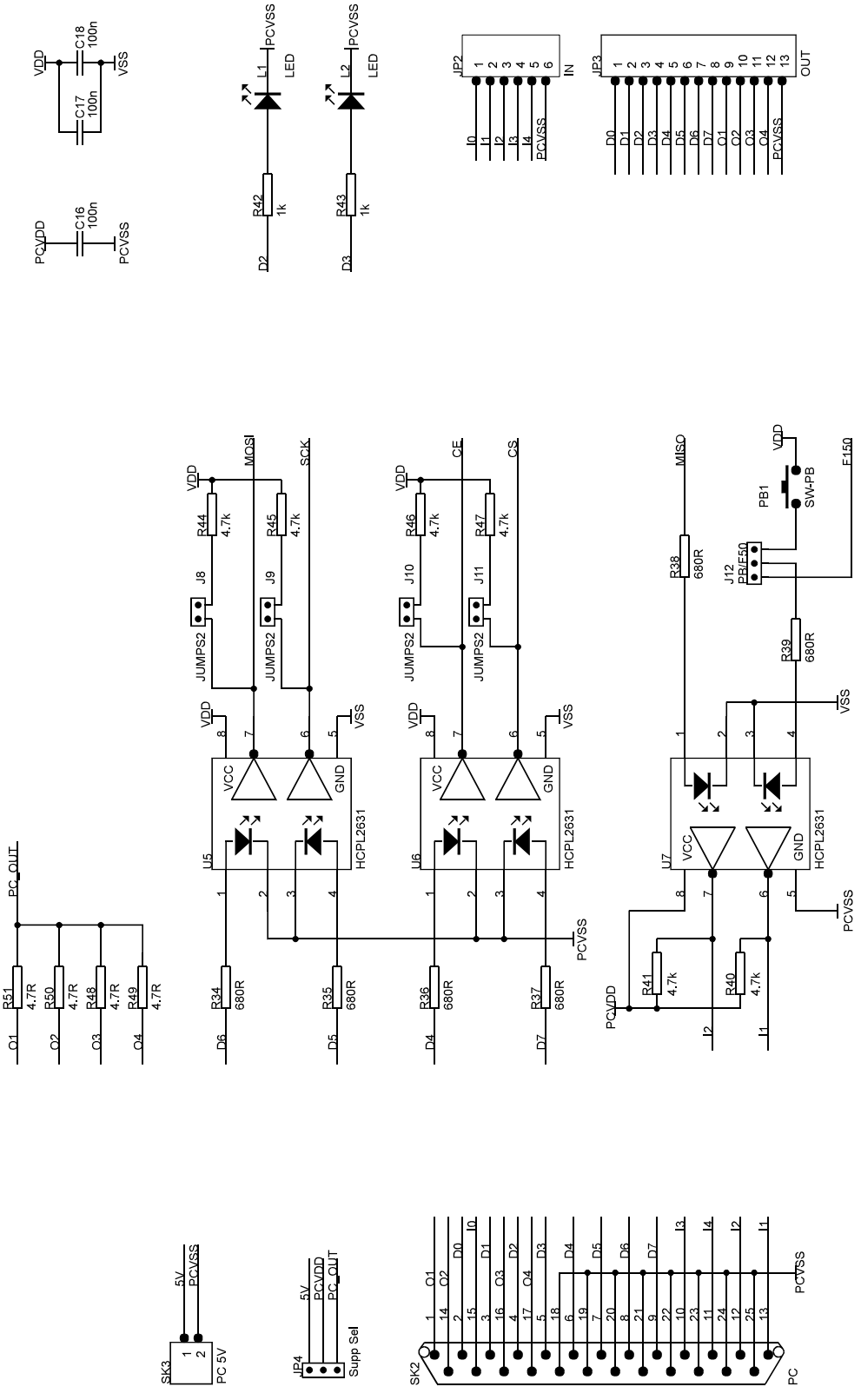


Figure 16: Schematic diagram of Isolated interface

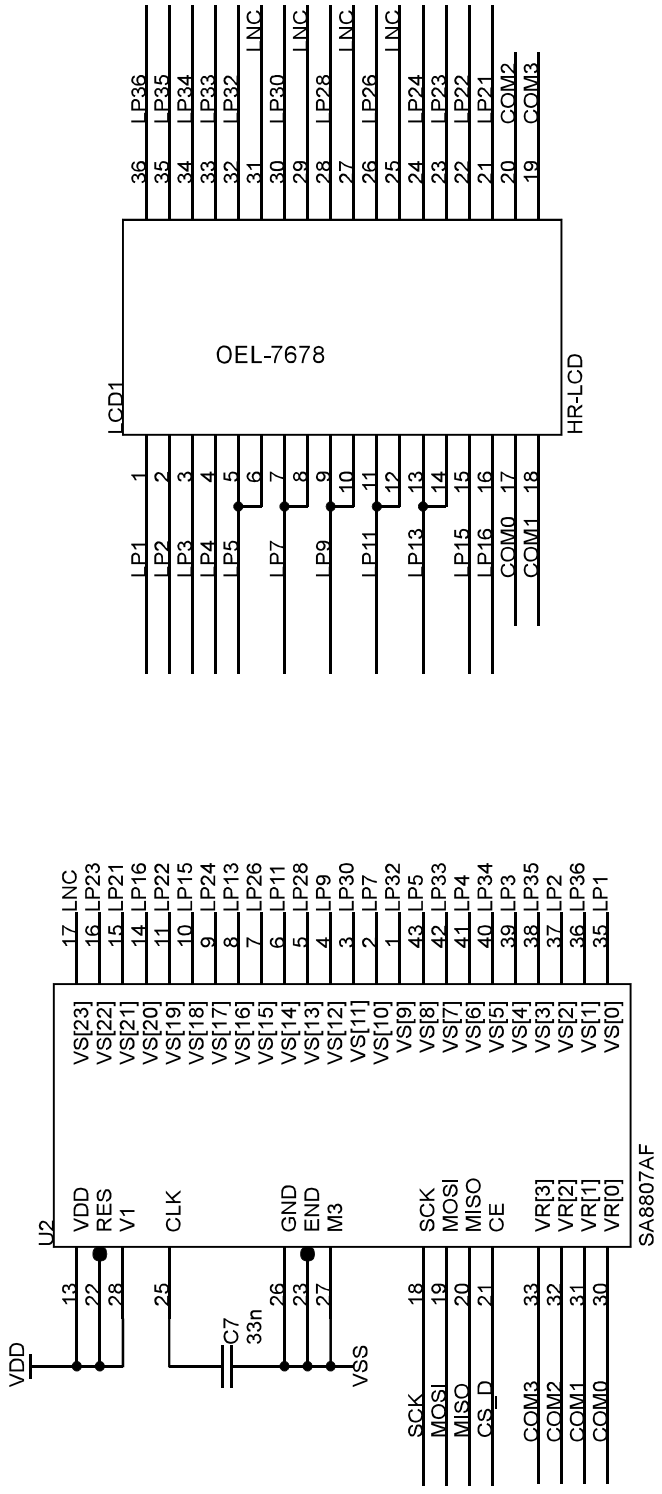


Figure 17: Schematic diagram of LCD and Driver

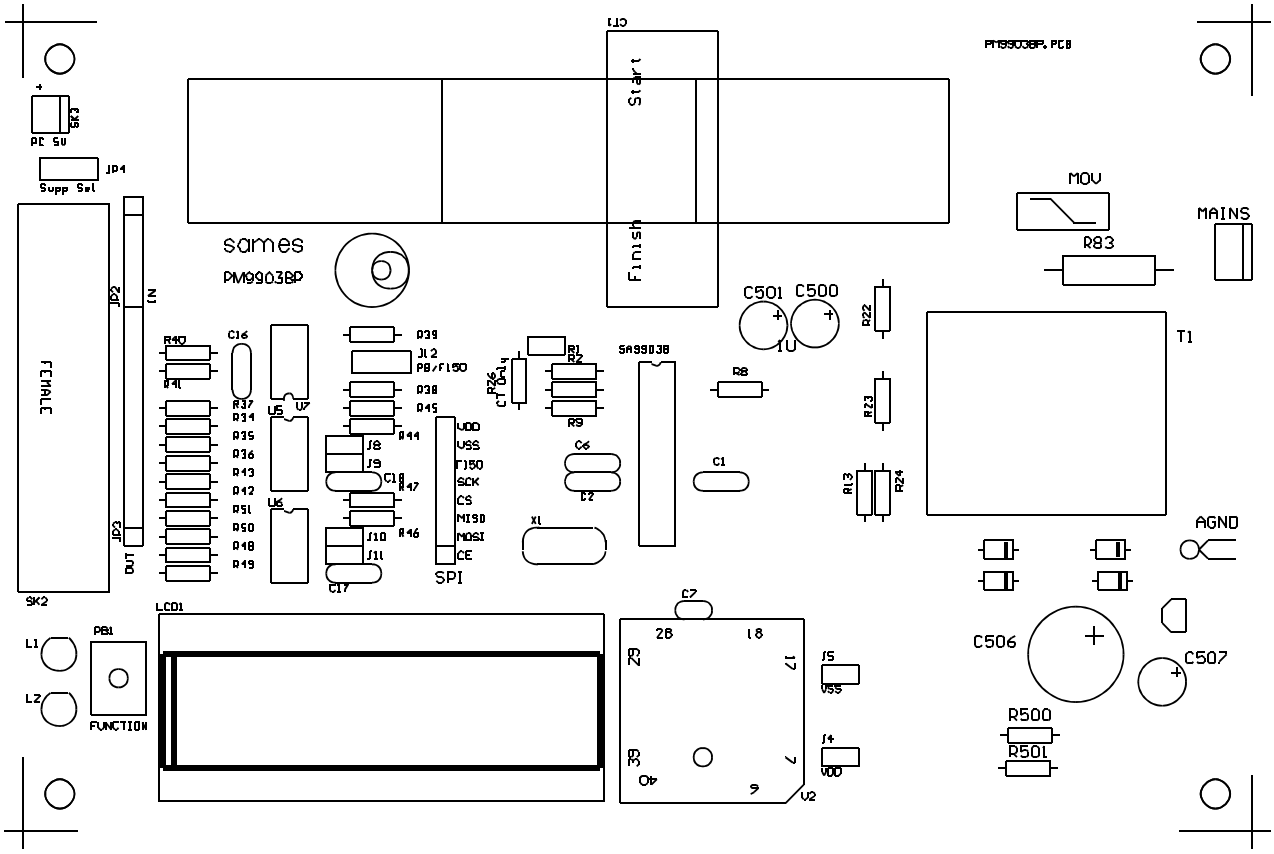


Figure 18: Silkscreen PCB layout

PCB LAYOUT

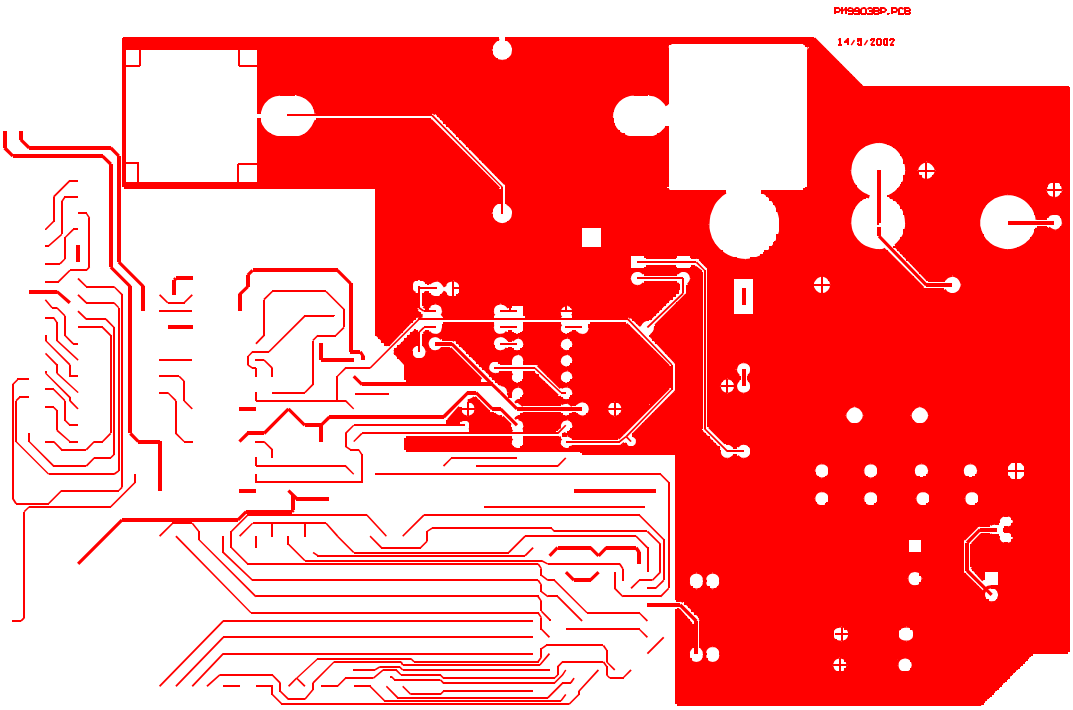


Figure 19: Top PCB layout

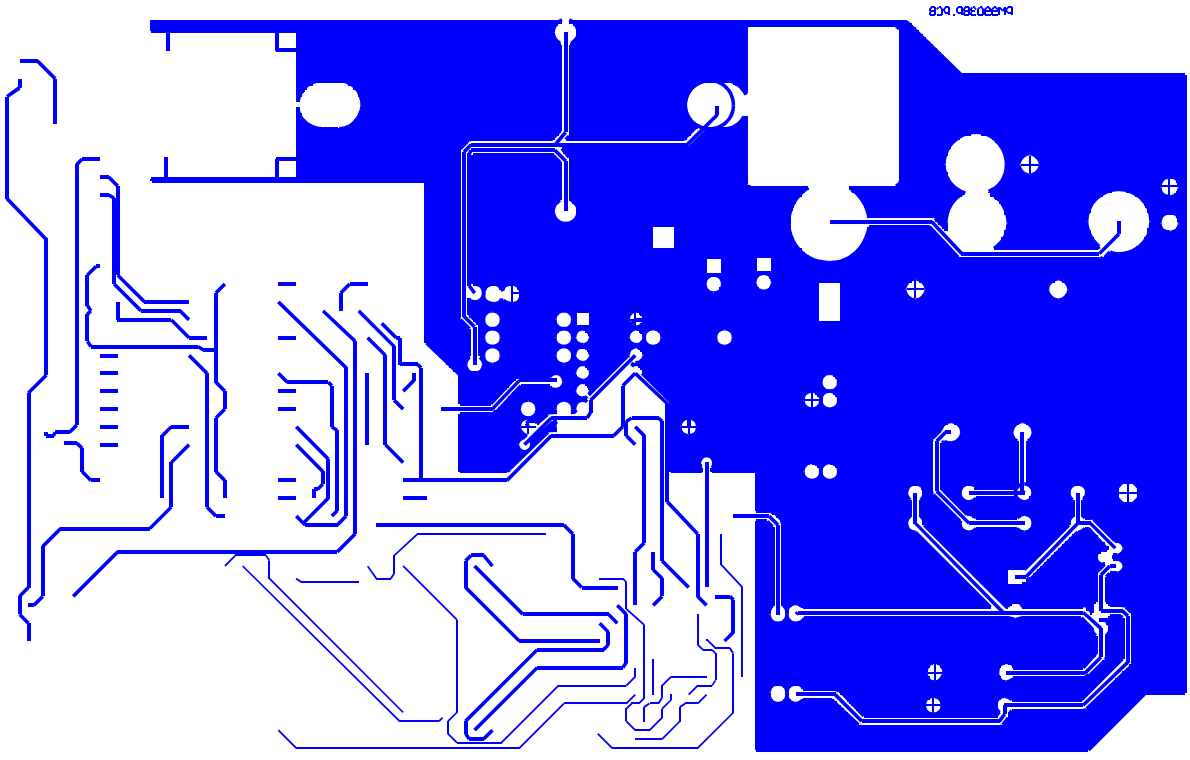


Figure 20: Bottom PCB layout

COMPONENT LIST (PM9903BPE BOARD)

Designator	Value	Description	Detail
C1, C2	220n	Capacitor Monolithic Ceramic	
C6	1µ	Capacitor Monolithic Ceramic	
C7	33n	Capacitor Monolithic Ceramic	
C16, C17, C18	100n	Capacitor Monolithic Ceramic	
C501, C500	1µ / 16V (C501 optional)	Capacitor Electrolytic Radial, Non-Polar	Note 1, a
C506	2200µ / 25V	Capacitor Electrolytic Radial	
C507	220µ / 16V	Capacitor Electrolytic Radial	
CT1	Tz76	Optional	
D1, D2, D3, D4	1N4148	Silicon Diode	
L1, L2	LED	LED 3mm Diameter	
PB1	SW-PB	Micro switch, push to make	
R1, R2	1k6	¼ Watt, 1%, Metal Film Resistor	Note 2
R8	1M	¼ Watt, 1%, Metal Film Resistor	
R9, R13	24k	¼ Watt, 1%, Metal Film Resistor	
R23, R22, R24	120k	¼ Watt, 1%, Metal Film Resistor	
R26	2R7	¼ Watt, 1%, Metal Film Resistor	Note 1, b
R34, R35, R36, R37, R38, R39	680R	¼ Watt, 5%, Carbon Resistor	
R40, R41, R44, R45, R46, R47	4k7	¼ Watt, 5%, Carbon Resistor	
R48, R49, R50, R51	4R7.....12R	¼ Watt, 5%, Carbon Resistor	
R42, R43, R500, R501	1k	¼ Watt, 5%, Carbon Resistor	
R83	10R	2 Watt, 5%, Wire Wound Resistor	
SHUNT	80A / 50mV (625µΩ)	Shunt Resistor	
Sk1	MAINS	2 Pin Molex, Center square pin, Friction Lock	
Sk2	PC	Db25, PCB Mount, Female	
Sk3	PC 5V	2 Pin Molex, Center square pin, Friction Lock	
T1	Transformer	9V, 1.5VA	
U1	SA9903B	20 Pin IC Socket, Tulip Type	
U2	SA8807AF	44 Pin PLCC IC Socket	
U3	78L05	TO-92 Package	
U5, U6, U7	HCPL2631	DIP 8 Package	
X1	3.5795MHz	Crystal	
Z1, (MOV)	S10 / 275	Metal Oxide Varistor	

Notes:

1. Use only with CT
   (a) else replace with wire-line
   (b) else leave open
2. For CT value will change

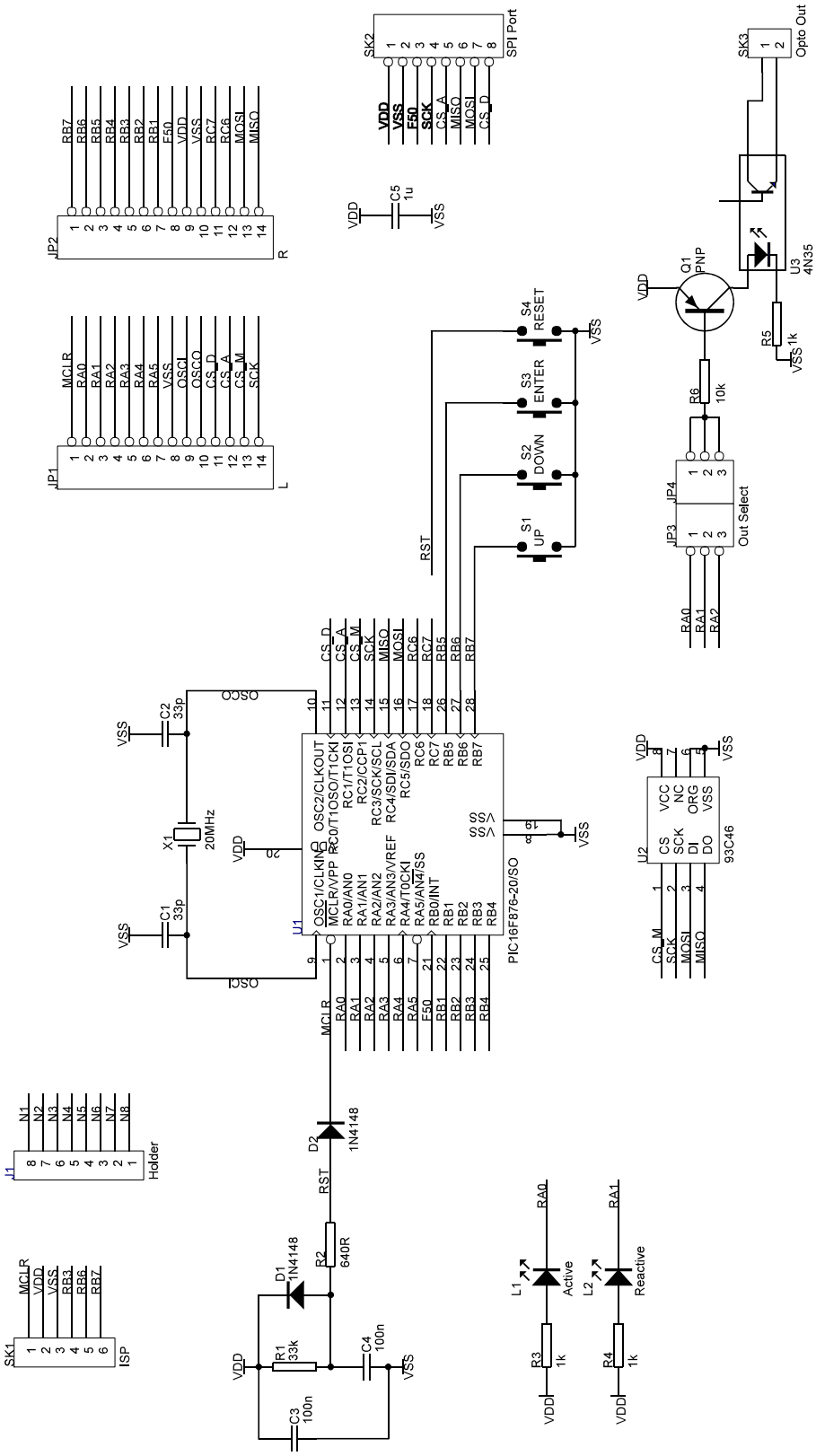


Figure 21: Micro-Controller Board Schematic

MICRO-CONTROLLER BOARD

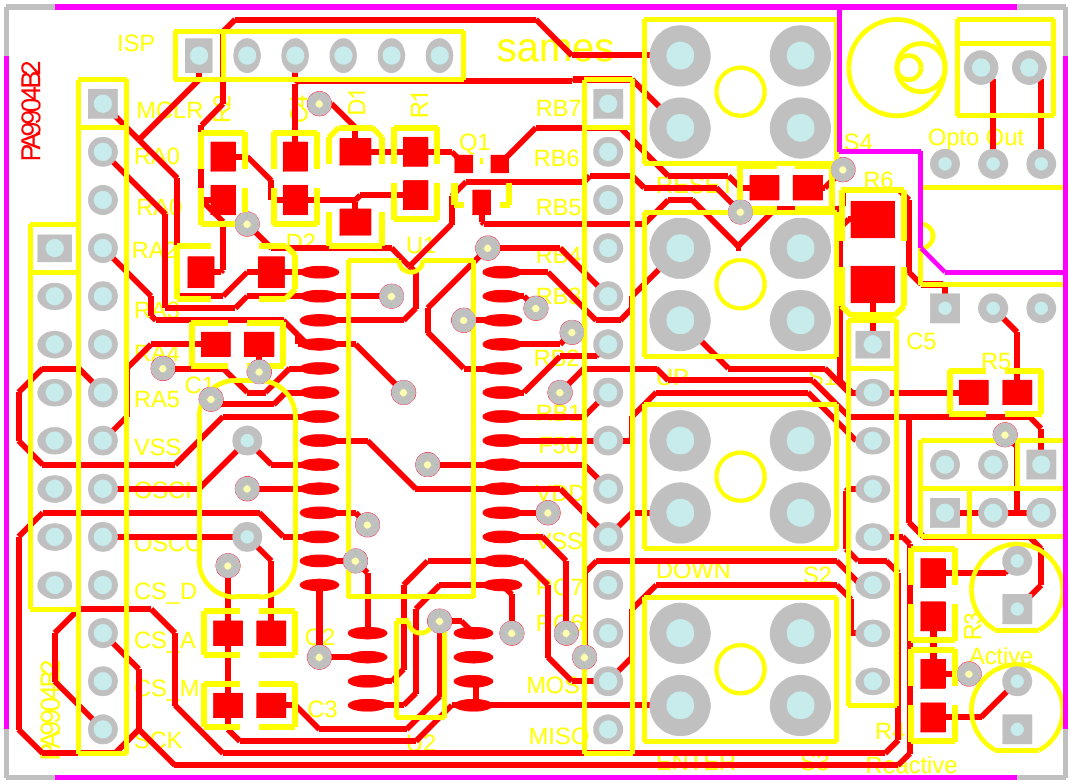


Figure 22: Top PCB layout

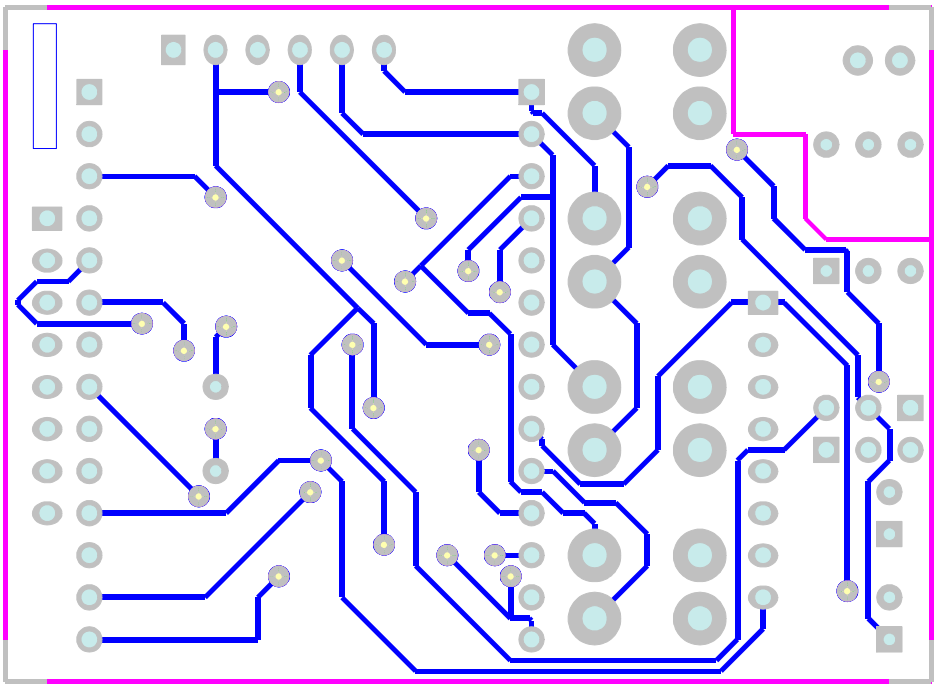


Figure 23: Bottom PCB layout

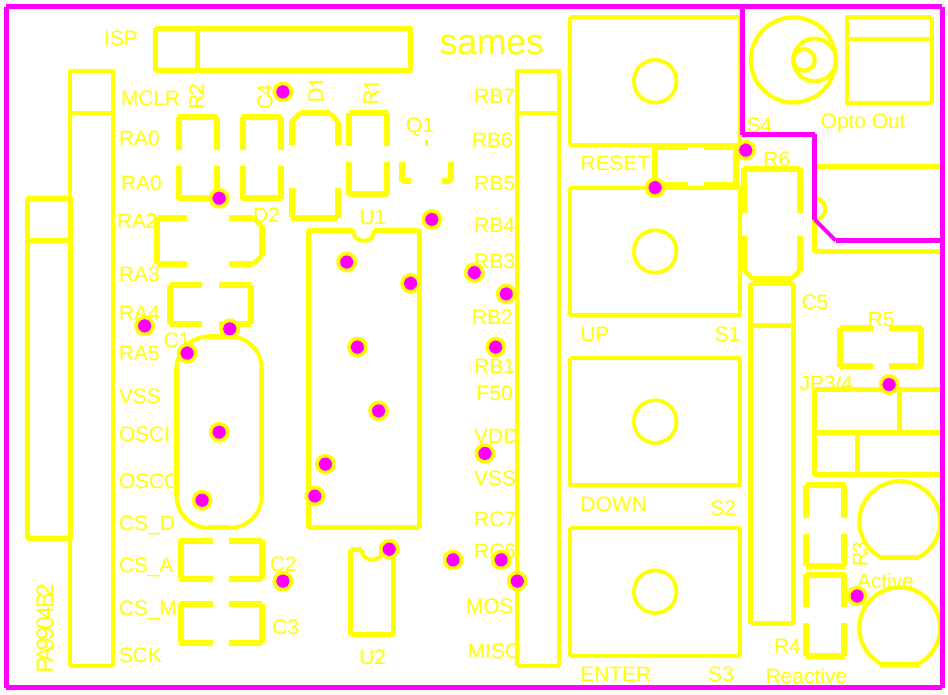


Figure 24: Silkscreen PCB layout (Micro-controller board)

COMPONENT LIST (Micro-controller board)

Designator	Value	Description
D1	1N4148	Si signal diode
D2	1N4148	Si signal diode
R5	1k	Resistor, 1%
R4	1k	Resistor, 1%
R3	1k	Resistor, 1%
C5	1u	Capacitor, tantalum/10V
U3	4N35	Opto-coupler, medium speed
R6	10k	Resistor, 1%
X1	20MHz	Crystal
R1	33k	Resistor, 1%
C2	33p	Capacitor, ceramic
C1	33p	Capacitor, ceramic
U2	93C46	e^2prom, 1kB
C3	100n	Capacitor, ceramic
C4	100n	Capacitor, ceramic
R2	100R....1kΩ	Resistor, 1%
L1	Active	3mm red
S2	DOWN	Micro switch, push to make
S3	ENTER	Micro switch, push to make
JP4	HEADER 3	3 pin SIP pins
J1	Holder	8 pin SIP socket
SK1	ISP	6 pin SIP pins
JP1	L	14 pin SIP pins
SK3	Opto Out	2 Pin Molex, Centre square pin, Friction lock
JP3	Out Select	3 pin SIP pins
U1	PIC 16F876-20/SO	Micro-controller
Q1	PNP	Any Si PNP, e.g. SMBT3906
JP2	R	14 pin SIP pins
S4	RESET	Micro switch, push to make
L2	Reactive	3mm green
SK2	SPI Port	8 pin SIP socket
S1	UP	Micro switch, push to make

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