

Evaluation Board for the SA9904B Energy Metering IC



sames

PM9904BPD

FEATURES

- Designed to be used together with accompanying software as fully functional three phase trivector meter.
- Better than class 1 operation.
- On board power supply.
- Two on-board LED's for active and reactive pulse output.
- 3 Phase 4 wire configuration.
- On-board LCD display.
- On-board current transformers.
- Isolated connection to PC parallel port.
- Easy accessible test pins.
- Micro-controller plug-in support

DESCRIPTION

This application note describes the PM9904BPD evaluation board and together with the SA9904B data sheet provides a complete evaluation platform. The SA9904B 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 of SA9904B can be found in its datasheet.

The PM9904BPD module is designed for a three-phase four-wire applications, referenced to neutral. The mains voltages easily connect to module by way of a Molex connector (SK1). The 3 on-board current transformers measures the current in each phase. A simple capacitive power supply supplies the energy metering IC with power. The LM431 regulators are used to generate a 5 V supply voltage for the on-board opto-couplers. Provision has been made to connect an external 5V power supply to drive the isolated opto-coupler.

The SA9904B 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 PM9904BPD 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 PM9904BPD module can easily be connected to a micro-controller. The SAMES micro-controller board connects to the evaluation module by means of JP1 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.

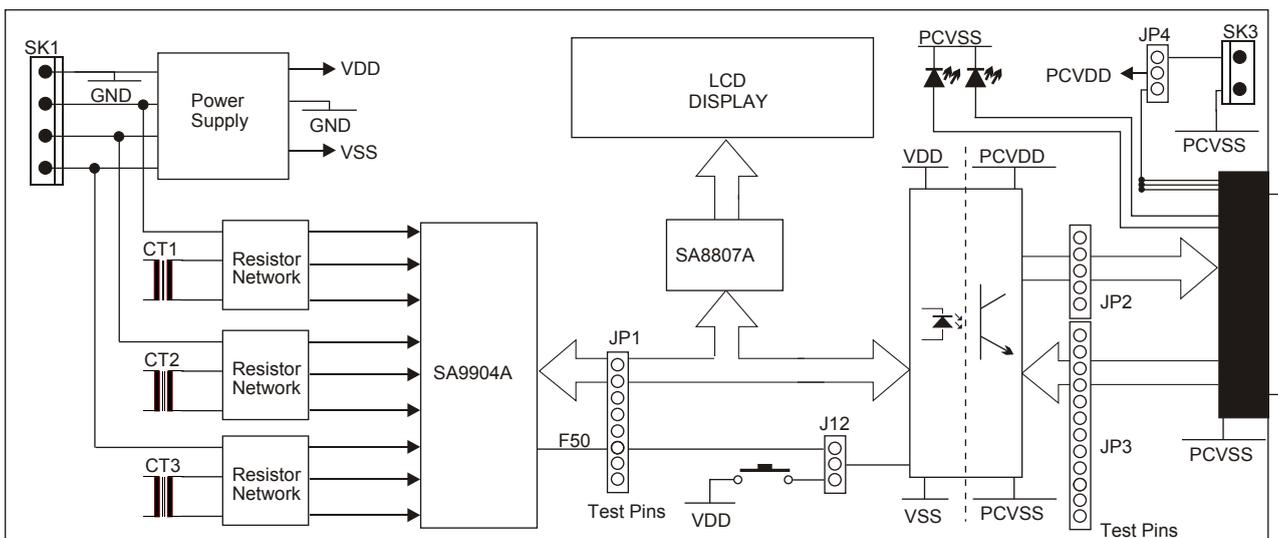


Figure 1: Block diagram



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 VDD to the metering circuitry. Default closed
J5	Connects VSS to the metering circuitry. Default closed
J6	GND connection point.
J7	Connection point between the power supply GND (N) and the SA9904 GND. Default closed

Voltage selection jumpers

The following jumpers are used to select between 115V and 230V operation. When closed the series resistance in the voltage divider circuits to the voltage sense inputs are halved. Default Open.

Jumper	230V	115V
J1	OPEN	Closed
J2	OPEN	Closed
J3	OPEN	Closed

Communication jumpers

Jumpers J8 to J11 connect pull up resistors to the SPI inputs of the SA9904. The pull up resistors are required by the open drain outputs of the HCPL2631 opto-couplers. If a PC is used

with the PM9904BPD 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.

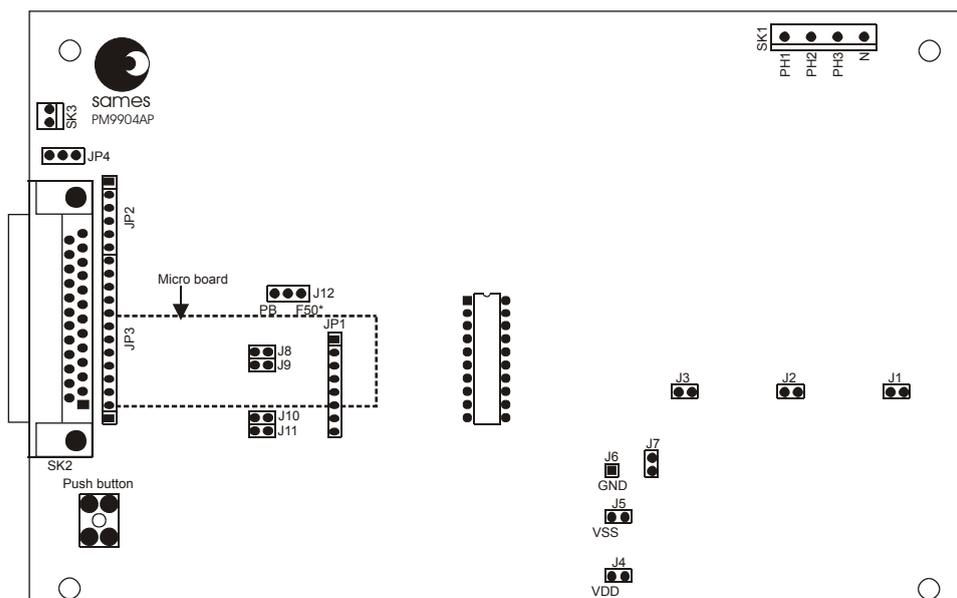
An additional output from the module is made available to the parallel port of the PC. The output can be selected to be the SA9904B's F50 output or it can be selected to be the modules push button output.

Jumper	Description
J12	PB (left connection) - Connects the push button output through a opto-coupler to pin 13 of the parallel port F50 (right connection) - Connects pin 7 of the SA9904 through a opto-coupler to pin 13 of the parallel port

Parallel 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 f50 and f150 is the same connection.

Figure 2: Jumper positions



CONNECTOR DESCRIPTION

Jumper	Description																																				
SK1	Connects the three phase 4 wire 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 SA9904B and SA8807. Note that this connector is on the same potential as the SA9904B. Provision is made for VDD and VSS so that a board with a micro controller can be easily fitted without any additional wiring. Signals available on this connector are:																																				
	<table border="1"> <thead> <tr> <th>Pin number</th> <th>Signal</th> <th>SA9904 (U1)</th> <th>SA8807 (U2)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>VDD</td> <td>Pin 6</td> <td>Pin 13</td> </tr> <tr> <td>2</td> <td>VSS</td> <td>Pin 14</td> <td>Pin 26</td> </tr> <tr> <td>3</td> <td>F50</td> <td>Pin 7</td> <td>NC</td> </tr> <tr> <td>4</td> <td>SCK</td> <td>Pin 8</td> <td>Pin 18</td> </tr> <tr> <td>5</td> <td>CS</td> <td>Pin 13</td> <td>NC</td> </tr> <tr> <td>6</td> <td>MISO</td> <td>Pin 9</td> <td>Pin 20</td> </tr> <tr> <td>7</td> <td>MOSI</td> <td>Pin 12</td> <td>Pin 19</td> </tr> <tr> <td>8</td> <td>CE</td> <td>NC</td> <td>Pin 21</td> </tr> </tbody> </table>	Pin number	Signal	SA9904 (U1)	SA8807 (U2)	1	VDD	Pin 6	Pin 13	2	VSS	Pin 14	Pin 26	3	F50	Pin 7	NC	4	SCK	Pin 8	Pin 18	5	CS	Pin 13	NC	6	MISO	Pin 9	Pin 20	7	MOSI	Pin 12	Pin 19	8	CE	NC	Pin 21
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SETTING UP THE PM9904AP MODULE

Figure 3 below shows a typical setup for the PM9904BPD evaluation module. The three phase voltages are connected directly to SK1 and each corresponding phase current is wired through the on-board CT's. 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.

Figure 3 also shows the default jumper settings. The PM9904BPD evaluation module is setup by default for 3x 230V/80A operation. For 3x 115V operation jumpers J1, J2 and J3 need to be closed. Also capacitors C12, C13, and C14 values must be changed to 1uF / 150 VAC.

When these hardware settings have been verified the user has the choice of using the micro-controller board or a PC to evaluate the SA9904B further. Please note when using the PC the micro-controller board should be unplugged to prevent a bus contention on the SPI bus, 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.

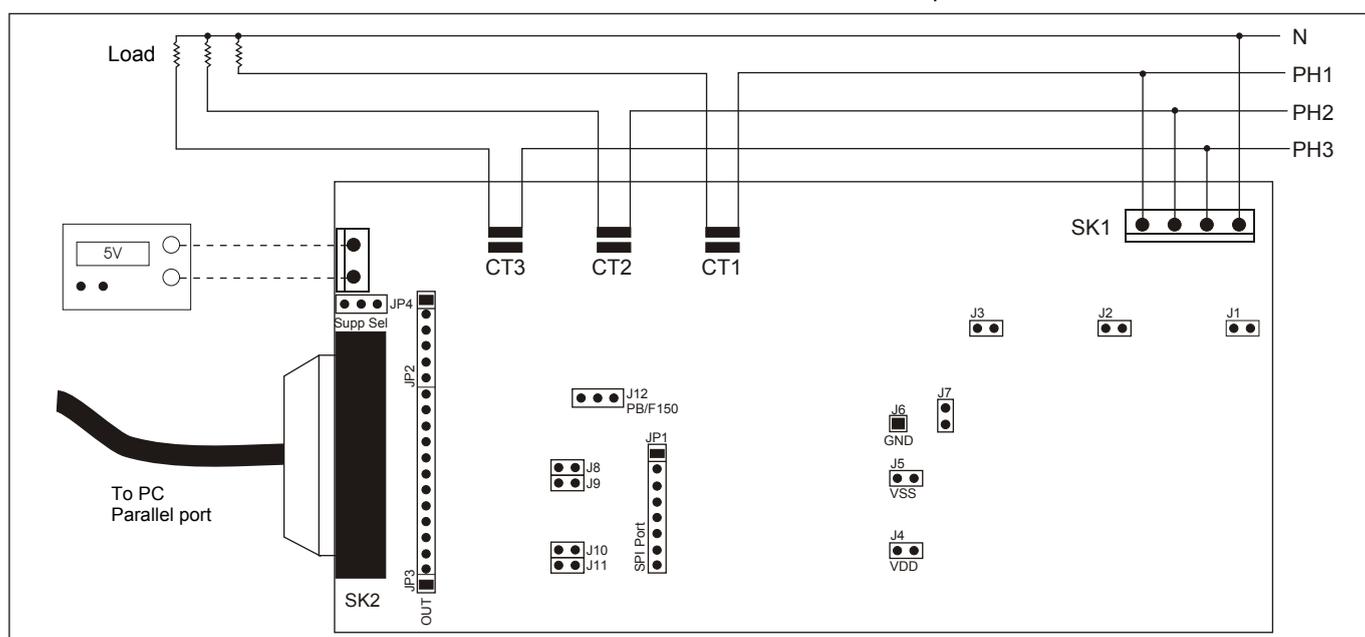


Figure 3: PM9904AP setup and connection



PM9904BPD EVALUATION SOFTWARE

Software for the SA9904AP module is supplied on one 3.5" 1.44MB floppy disk and is designed to communicate with the SA9904AP module via the PC's parallel port. The supplied software is written for DOS. Additional Windows software will be posted to the SAMES web site for downloading when available. The source code, written in Turbo C, is also included.

File description

The following files are included on the floppy disk:

9904mtr.c

This file contains the source for the functions that read the SA9904 registers, store these values in integration registers, check for any overflow and generate the corresponding energy pulse for the PM9904BPD on-board LED's. It makes provision to measure unbalanced energy per phase or sum the energy for each phase. 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 PM9904BPD 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.

9904mtr.exe

This is the executable file.

Running the software

The program is executed by running the 9904mtr.exe file with the following arguments:

9904mtr.exe 1 10

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

The second parameter is a loop delay. Larger values will slow down the SPI communication speed to the PM9904BPD module.

Getting the SA9904 to generate pulses proportional to the energy measured.

Figure 4 is a flow diagram showing how to generate pulses proportional to energy measured by the SA9904A. The speed of execution is not critical, although it will influence the resolution of the pulses that is generated.

It is recommended that the flow diagram be implemented together with a timer interrupt used for the creep timing. The same flow diagram is applicable for the SA9604A, but reading of the register values should be synchronized with changes in bit D19 of its frequency register.

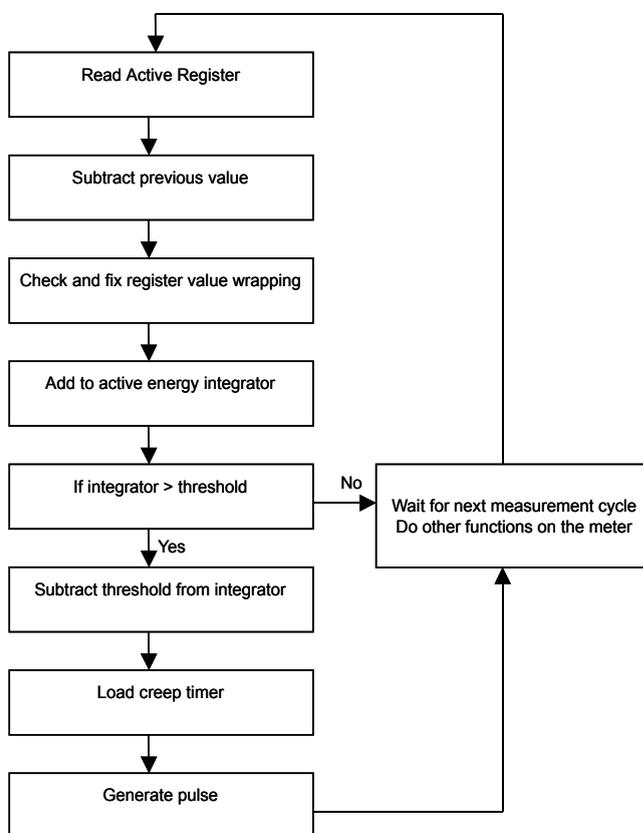


Figure 4: Pulse flow diagram

Threshold and pulse rates

The active and reactive registers on the SA9904B 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 = Vnom x Imax / 320 000



where:

Vnom is the mains voltage and correspond to 14µA in the voltage inputs of the SA9904B.

Imax is the maximum mains current to be measured and correspond to 16µA on the current inputs of the SA9904B.

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 in Ws/pulse

Energy per LED pulse is (Ws/pulse):

$$Epp \text{ energy} = 1000 \times 3600 / Mpr$$

where:

Epp is energy per LED pulse

Mpr is the meter pulse rate or meter constant in pulses/kWh

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

$$\text{Active energy threshold} = Epp / Epc$$

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

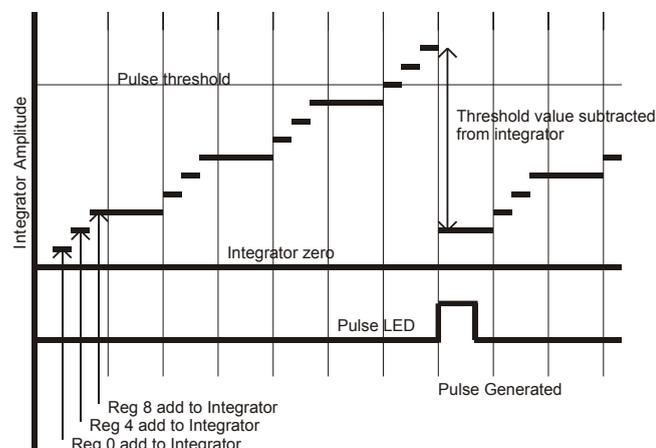


Figure 5: Implementation of an overflow integrator

Meter creep current

For the SA9904B 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):

$$Rf = (Vnom \times Imax / 1000) \times (Mpr / 3600)$$

where:

Vnom is the mains voltage and correspond to 14µA in the voltage inputs.

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

Mpr is the meter pulse rate in pulses/kWh.

Creep threshold time (s):

$$Ct = 1 / (Cc / Imax) \times Rf$$

where:

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

Imax 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.

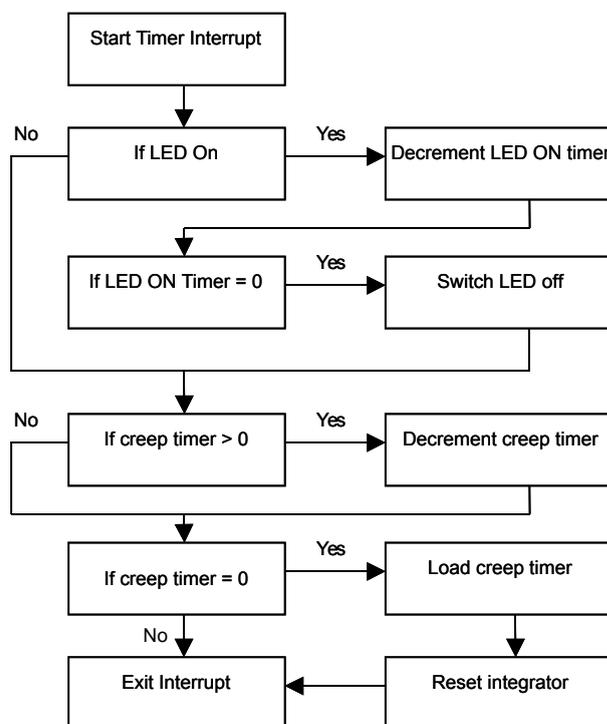


Figure 6: Interrupt flow diagram



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.

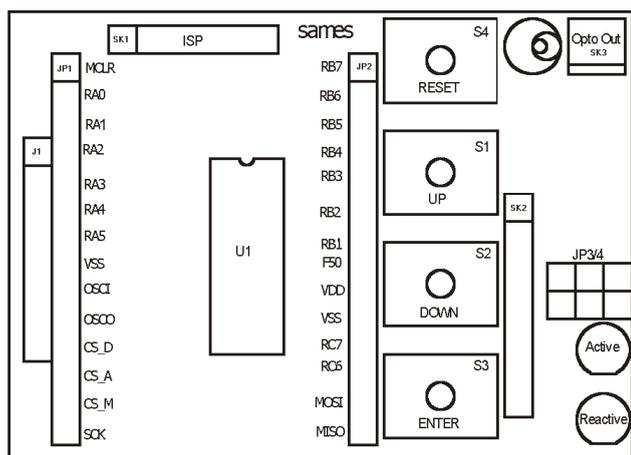


Figure 7: Micro-controller board

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
- and miscellaneous 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 optocoupler 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.

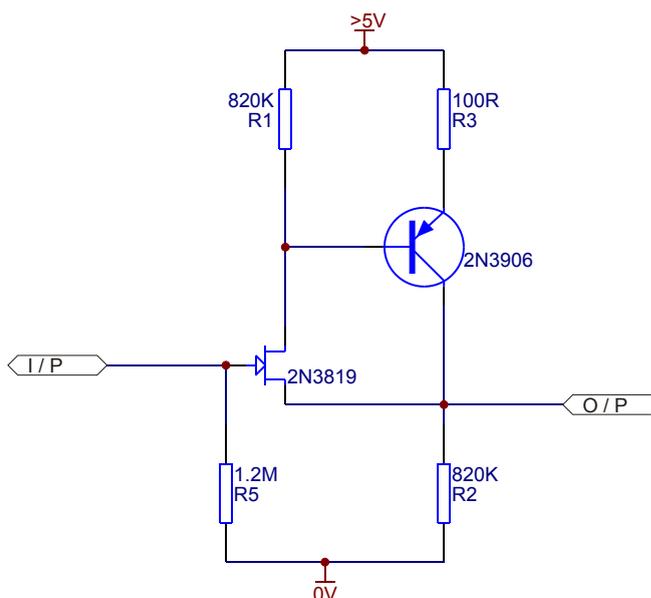


Figure 8: Typical buffer circuit



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 best (or only) possible implementation. The code was generated using Hi-Tech PIC C (v7.86PL4); the demo version on their www site (www.htsoft.com) is sufficient for experimentation. The program flow is presented in Figure 9.

SPI

Bit-banging SPI is used to aid portability to other micros, i.e. three port pins under direct software control creates SPI_CLOCK, MOSI and reads MISO. The SPI access of the SA9904B is divided into two tasks namely, fast and slow changing data. This is accomplished via an interrupt driven time-slicing architecture, with a basic timer tick of 10ms.

Rate LEDs / opto-outputs

The 10ms pulse widths on these outputs are derived from the basic timer tick.

Creep

The creep algorithm is simply: - 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.

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 displays per phase voltage and frequency data, each press shows the next phase's data.

Memory Usage

ROM:
4070 words or 50% of the total capacity

RAM:
Bank₀ 86%
Bank₁ 26%
Bank₂ 83%
Bank₃ --- or 50% 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.

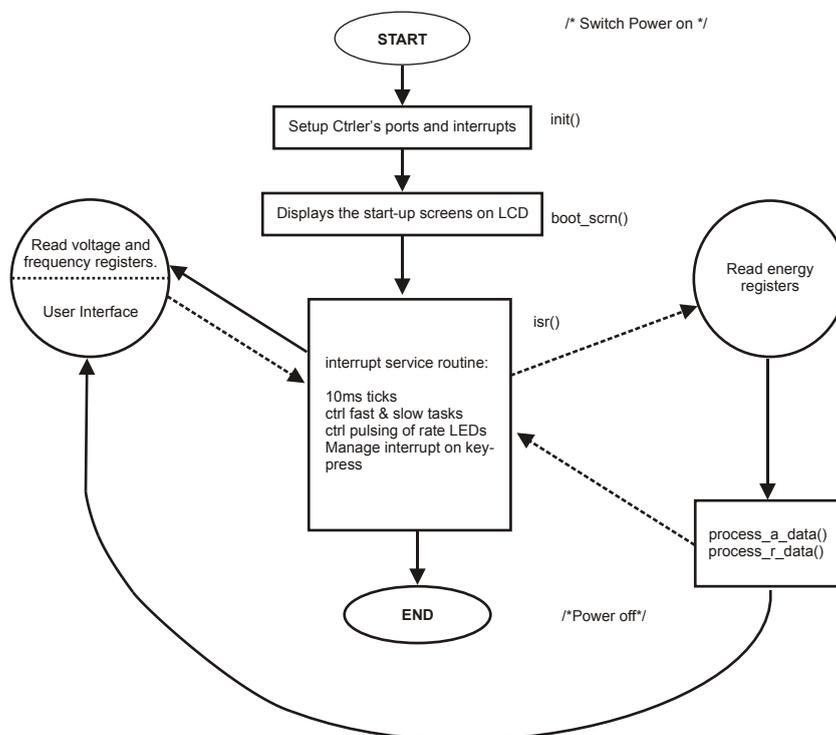


Figure 9: Program flow



CIRCUIT DESCRIPTION

ANALOG SECTION

The analog (metering) interface described in this section is designed for measuring 3 x 230V/80A with precision better than Class 1.

The most important external components for the SA9904B 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 (SA9904B pin 15) is connected to Vss via R7 which determines the on chip bias current. With R7=47kΩ optimum conditions are set. VREF does not require any additional circuitry.

CT Termination Resistor

The voltage drop across the CT termination resistors should be at least 16mV at rated current (Imax). The on-board CT's have low phase shifts and have a ratio of 1:2500. Each CT is terminated with a 2.7Ω resistor resulting in a voltage drop of 86.4mV across each resistor at rated conditions.

Current Sense Resistors

Referring to figure 10 the resistors R1 and R2 define the current level into the SA9904B's current sense inputs (phase one IIP1 and IIN1). 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:

$$\begin{aligned}
 R1 = R2 &= (I / 16\mu A) \times RSH / 2 \\
 &= 80A / 2500 / 16\mu A \times 2.7\Omega / 2 \\
 &= 2.7k\Omega
 \end{aligned}$$

where:

I = Line current / CT Ratio

The three current channels are identical so R1 = R2 = R3 = R4 = R5 = R6.

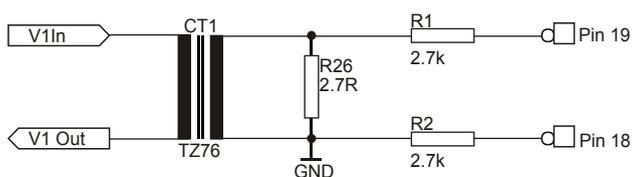


Figure 10: Current input configuration

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 14μARMS at nominal mains voltage. This voltage sense input saturates at approximately 17μARMS. 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:

$$RA = R22 + R23 + R24 + R25$$

$$RB = R8 \parallel R13$$

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:

$$RB = 23.44k\Omega$$

$$RA = RB \times (230V / 14V - 1)$$

$$RA = 361.6k\Omega$$

Resistor values of R22, R24 are chosen to be 82kΩ and resistors R23 and R25 is chosen to be 120kΩ each.

The three voltage channels are identical so R14=R16=R17=R18=R20=R22=R24= 82kΩ and R15=R17=R19=R21=R23=R25= 120kΩ

The capacitors C3, C4 and C5 is used to compensate for phase shifts between the SA9904's voltage sense inputs and current sense inputs. The on-board CT's were characterized and found to have a constant phase shift of 0.18 degrees. The value of the phase shift compensation capacitors were calculated as follows:

$$C = 1 / (2 \times \pi \times \text{Mains frequency} \times R5 \times \tan(\text{Phase shift angle}))$$

$$C = 1 / (2 \times \pi \times 50\text{Hz} \times 1M\Omega \times \tan(0.18 \text{ degrees}))$$

$$C = 1.013\mu F$$

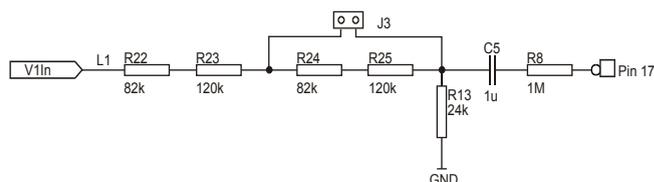


Figure 11: Mains voltage divider



Power Supply

Referring to figure 15, capacitor C10 is charged through D2 during the positive half of the sine wave from the R29, C12 mains voltage dropper. Identical charging circuitry exists for the other two phases. During the negative sine wave, C11 is charged through diode D1. The unregulated voltage charged on C10 and C11 is limited to 47 V by means of zener diode D7. Resistors R32 and R33 act as current limiting resistors that feed the unregulated voltage to the positive and negative voltage regulators U3 and U4. The voltage regulators need a load capacitance of around 10 μ F (C8 and C9) to be in a stable operating region. C15 acts as a supply voltage storage capacitor.

Jumpers J4, J5 and J7 allow the power supply to be completely disconnected from the metering section from the device.

PCB DESIGN

The PM9904AP evaluation module represents a Class 1 meter and is designed to demonstrate the functionality and performance of the SA9904B metering integrated circuits. The SA9904B is mainly the analog front end of a meter. The SA9904B measures the energy, voltage and frequency which are made available to an external micro-controller, by way of JP1, or to a PC. When the meter's PCB is designed, it should be remembered that the SA9904B inputs are analog and special care need to be taken with the power supply and signal routing to the SA9904B.

Protection

The SA9904B should be protected from the measuring environment. This is achieved by using resistor dividers to scale all the SA9904B's input signals. MOV's Z1, Z2, Z3 together with resistors R29, R30, R31 protect the power supply capacitors 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 SA9904B's current sense inputs should be placed as close as possible to the SA9904B. This eliminates the possibility of any stray signals coupling into the input signals.

Ground Plane

The GND pin of the SA9904B is connected to the neutral phase, which is halfway between VDD and VSS. Note that supply bypass capacitors C1 and C2 are positioned as close as possible to the supply pins of the SA9904B, and is connected to a solid ground plane. Capacitor C6 is also positioned as close as possible to the supply pins of the SA9904B 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 SA9904B by means of capacitor C15. Care was taken not to have current flowing in the node that connects the voltage reference resistor to VSS 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 SA9904B 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 SA9904B.

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.

$$f = 7\mu\text{F} \times 0.1\text{Hz} / C$$

f = Required oscillator frequency

f / 8 = back plane multiplex rate for a 4 back plane display

SPI Interface

The SA8807A shares the SPI interface with the SA9904B and connects directly to the opto-couplers on the PM9904BPD evaluation board. The CE signal enables the SPI interface for the display driver and the CS signal enables the SPI interface for the SA9904B.



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.

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 SA8807A datasheet for more information.

Address

The address of the data is set up in the following manner

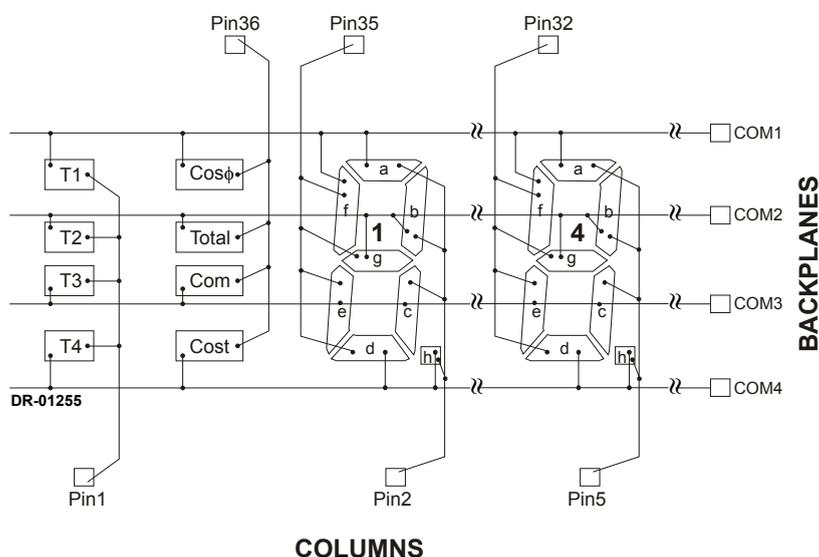


Figure 12: Mapping of a single character

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

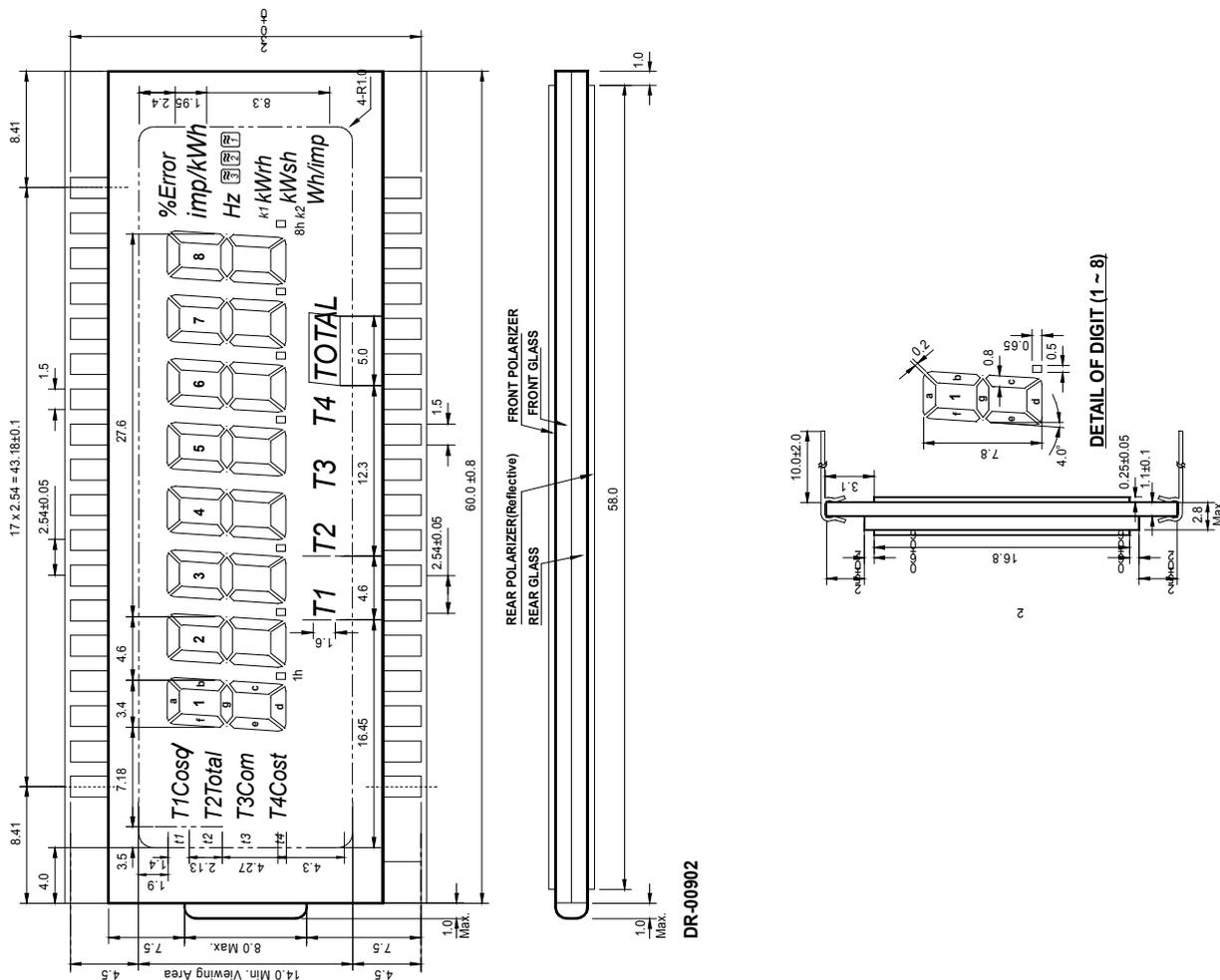


Figure 13: All the Icons and Dimensions of LCD

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

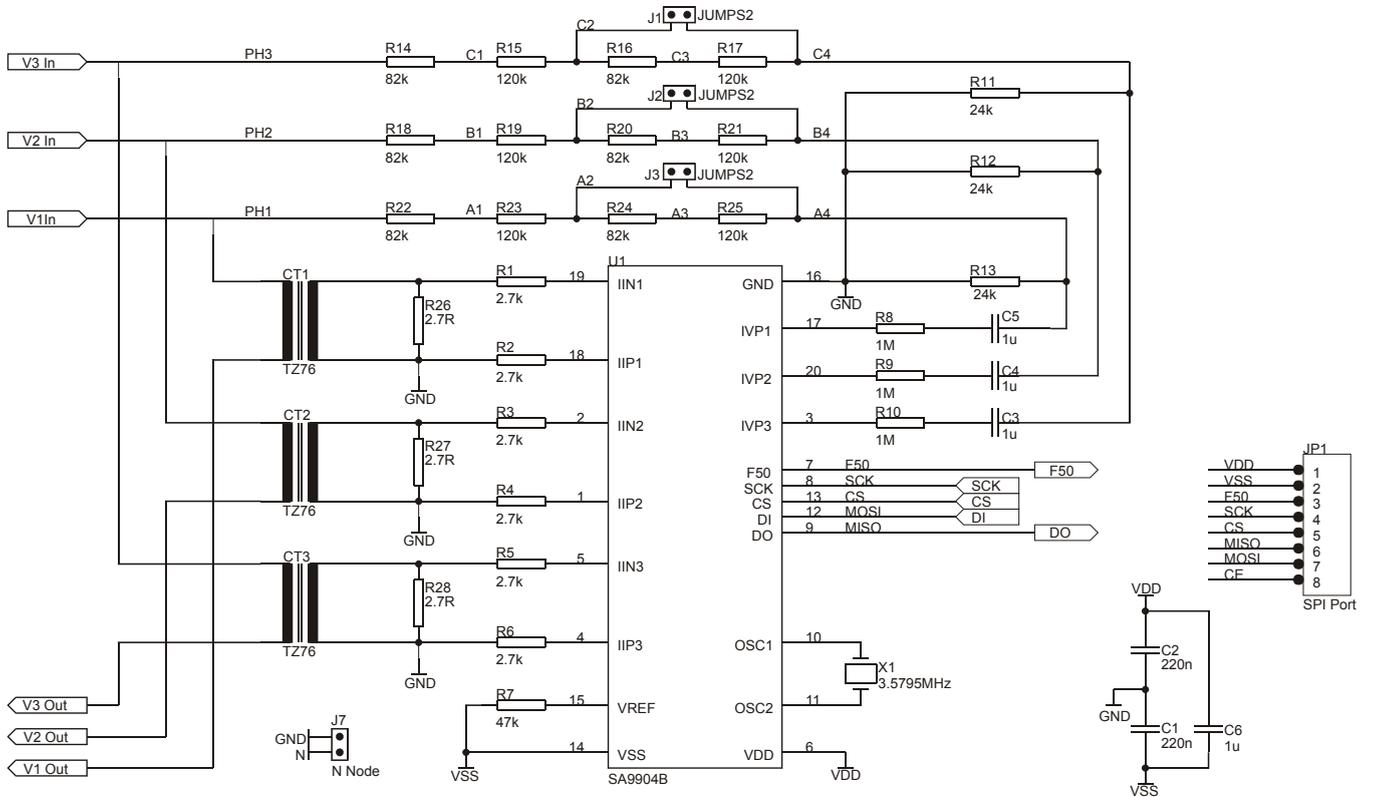


Figure 14 : Schematic diagram of metering section

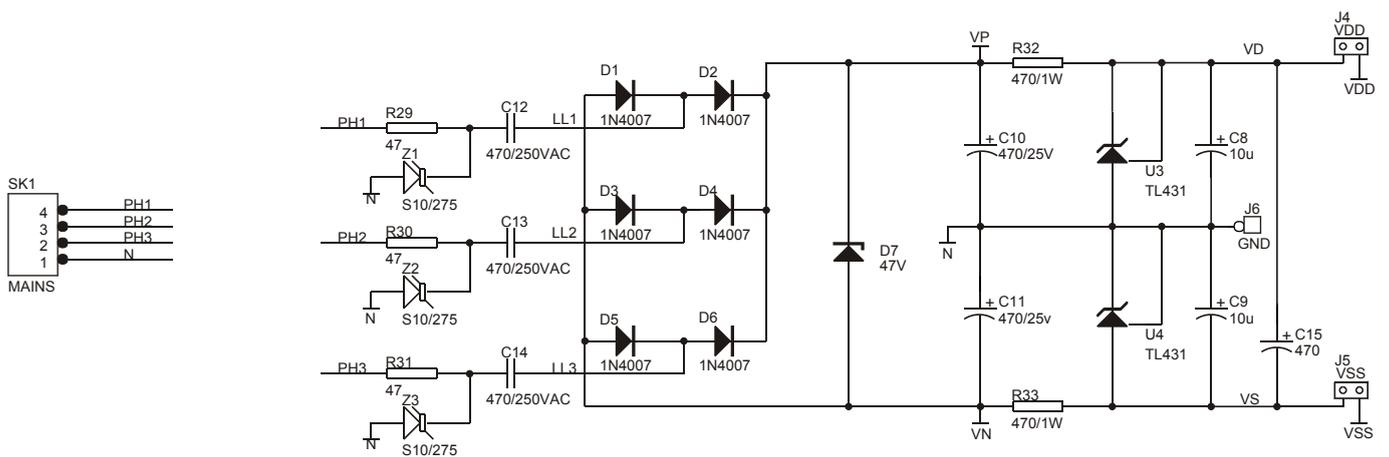


Figure 15: Schematic diagram of power supply

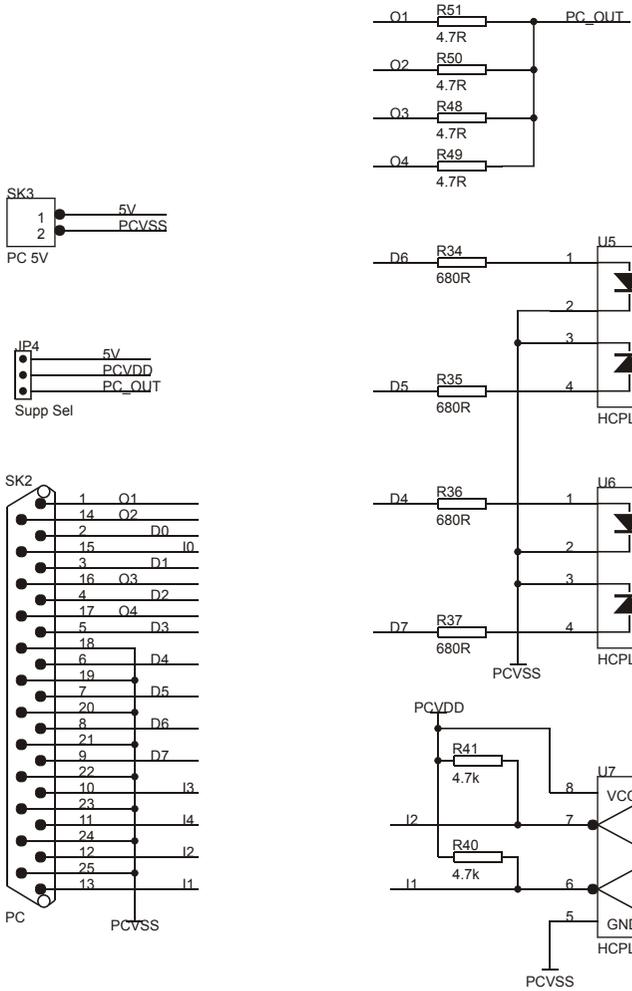
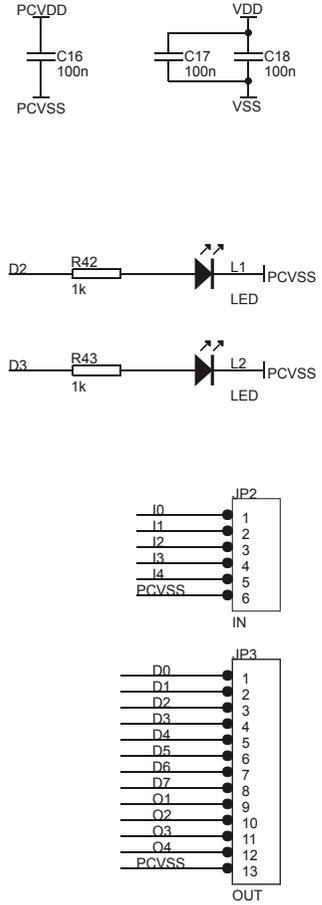


Figure 16: Schematic diagram of Isolated Interface

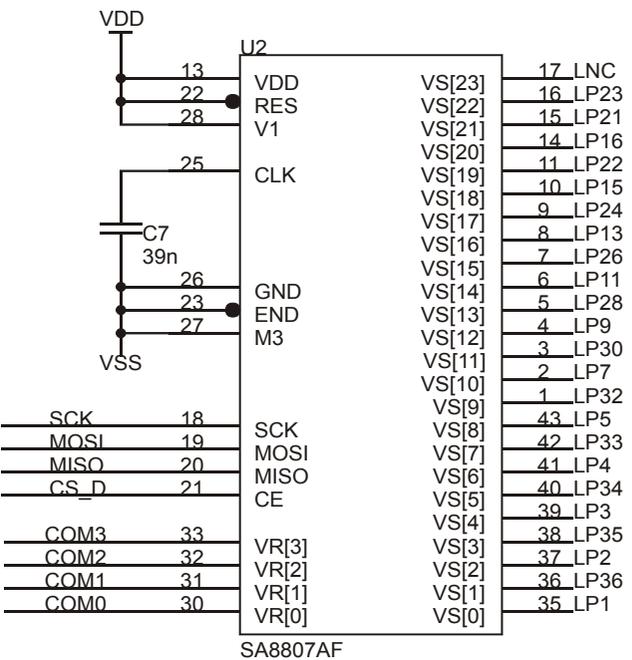
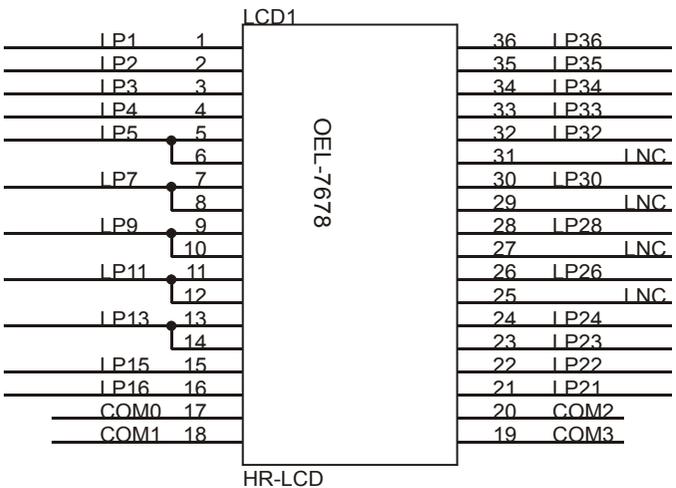


Figure 17: Schematic diagram of LCD and Driver

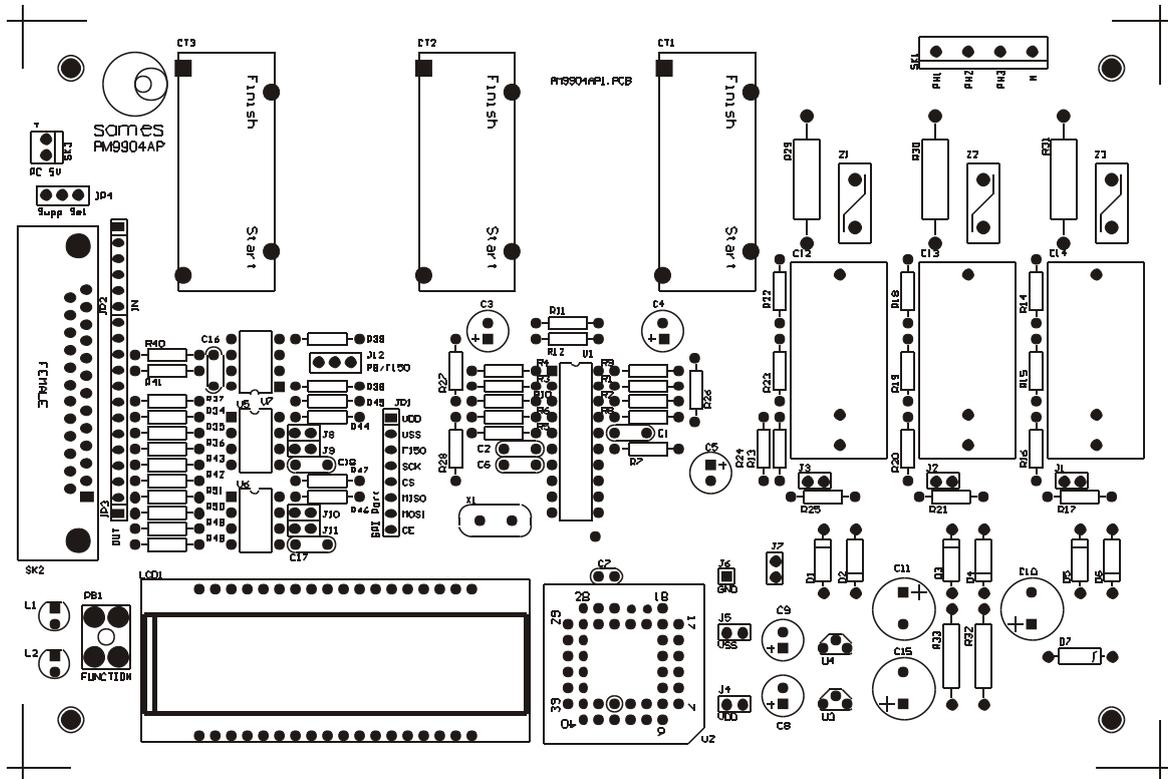


Figure 18: Silkscreen PCB layout



PCB LAYOUT

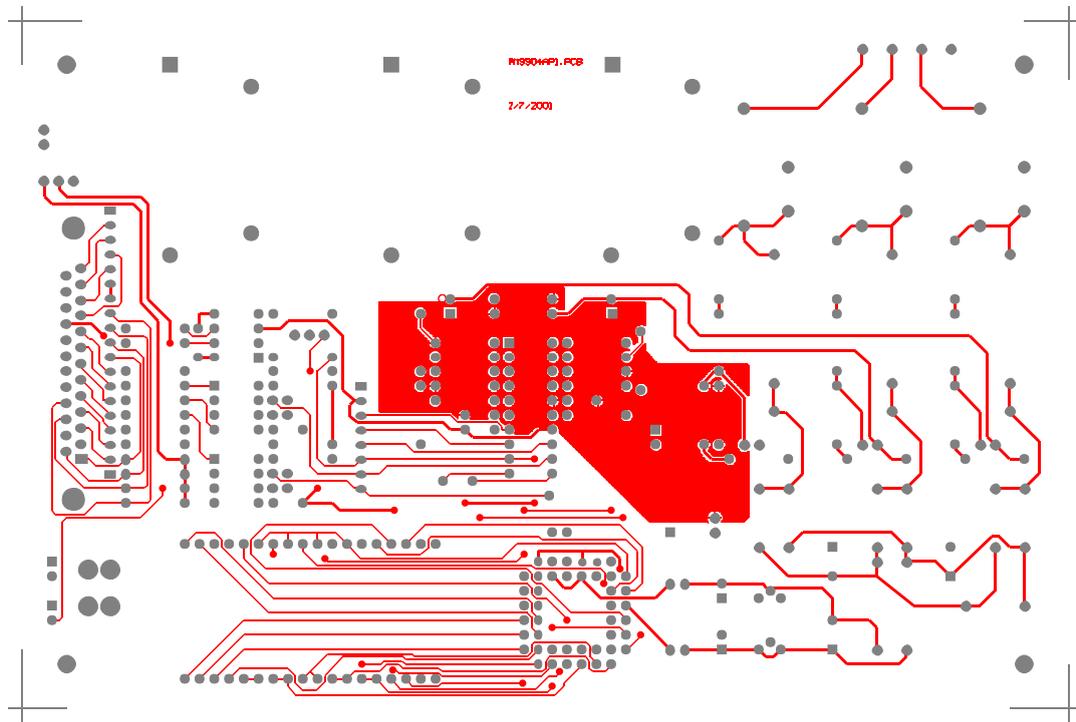


Figure 19: Top PCB layout

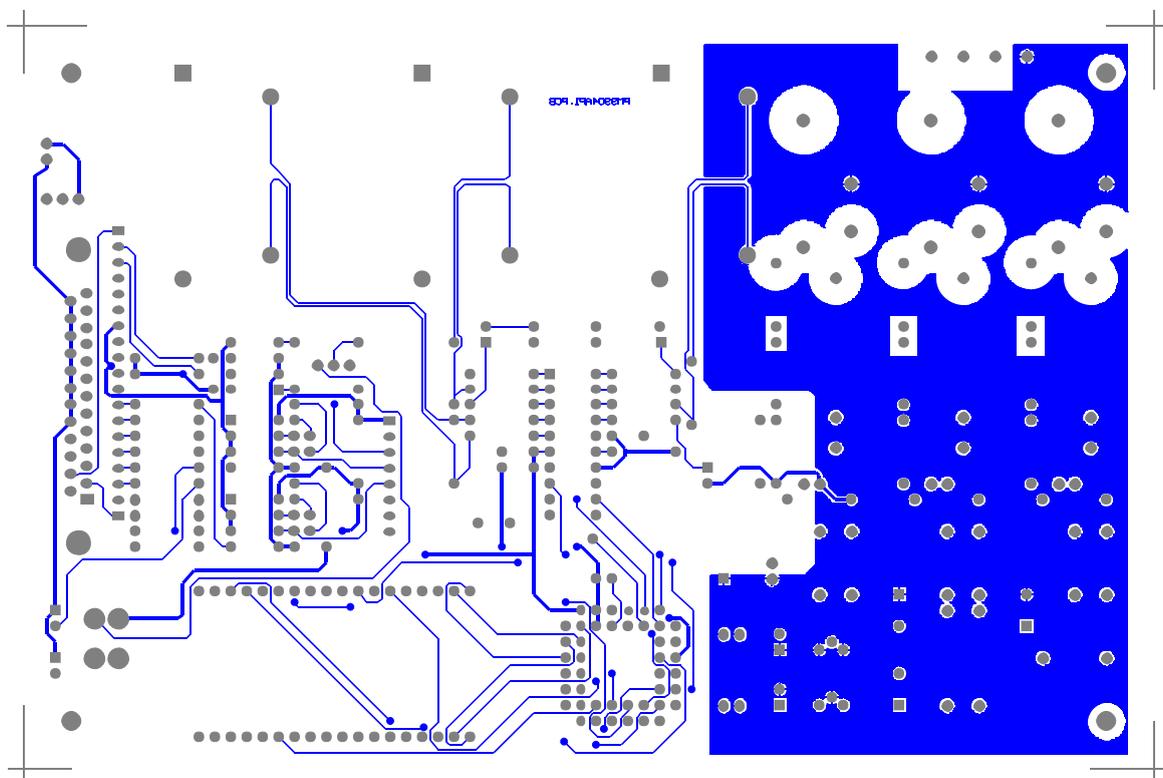


Figure 20: Bottom PCB layout

**COMPONENT LIST (PM9904BPD BOARD)**

Items	Part Type	Designator	Description
1	100n	C16, C17, C18	Capacitor Monolithic Ceramic
2	10 μ / 16V	C8, C9	Capacitor Tantalum
1	1 μ / 16V / No Polarity	C3, C4, C5	Capacitor Electrolytic Radial
2	1 μ / 63V	C6	Capacitor Monolithic Ceramic
4	220n / 63V	C1, C2	Capacitor Monolithic Ceramic
3	22n / 63V	C7	Capacitor Monolithic Ceramic
5	470n / 250VAC	C12, C13, C14	Capacitor Polyester
6	470 μ / 16V	C15	Capacitor Electrolytic Radial
5	470 μ / 25V	C10, C11	Capacitor Electrolytic Radial
6	Tz76	CT1, CT2, CT3	
7	1N4007	D1, D2, D3, D4, D5, D6	Rectifier Diode
9	47V	D7	Zener Diode
16	LED	L1, L2	LED 3mm Diameter
17	SW-PB	PB1	Micro switch
18	2.7k	R1, R2, R3, R4, R5, R6	¼ Watt, 1%, Metal Film Resistor
20	47k	R7	¼ Watt, 1%, Metal Film Resistor
20	1M	R8, R9, R10	¼ Watt, 1%, Metal Film Resistor
21	24k	R11, R12, R13	¼ Watt, 1%, Metal Film Resistor
22	4.7R	R48, R49, R50, R51	¼ Watt, 5%, Carbon Resistor
25	120k	R15, R17, R19, R21, R23, R25	¼ Watt, 1%, Metal Film Resistor
27	1k	R42, R43	¼ Watt, 5%, Carbon Resistor
26	2.7R	R26, R27, R28	¼ Watt, 1%, Metal Film Resistor
27	4.7k	R40, R41, R44, R45, R46, R47	¼ Watt, 5%, Carbon Resistor
29	470R / 1 Watt	R32, R33	1 Watt, 1%, Wire Wound Resistor
30	47R / 2 Watt	R29, R30, R31	2 Watt, 1%, Wire Wound Resistor
31	680R	R34, R35, R36, R37, R38, R39	¼ Watt, 5%, Carbon Resistor
33	82k	R14, R16, R18, R20, R22, R24	¼ Watt, 1%, Metal Film Resistor
35	MAINS	Sk1	7 Pin Molex, Center square pin, Friction Lock
37	PC	Sk2	Db25, PCB Mount, Female
36	PC 5V	Sk3	2 Pin Molex, Center square pin, Friction Lock
37	TL431	U3, U4	TO -92 Package
38	HCPL2631	U5, U6, U7	DIP 8 Package
39	3.5795 MHz	X1	Crystal
40	S10 / 275	Z1, Z2, Z3	Metal Oxide Varistor
41	SA9904B	U1	20 Pin IC Socket, Tulip Type
43	SA8807AF	U2	44 Pin PLCC IC Socket

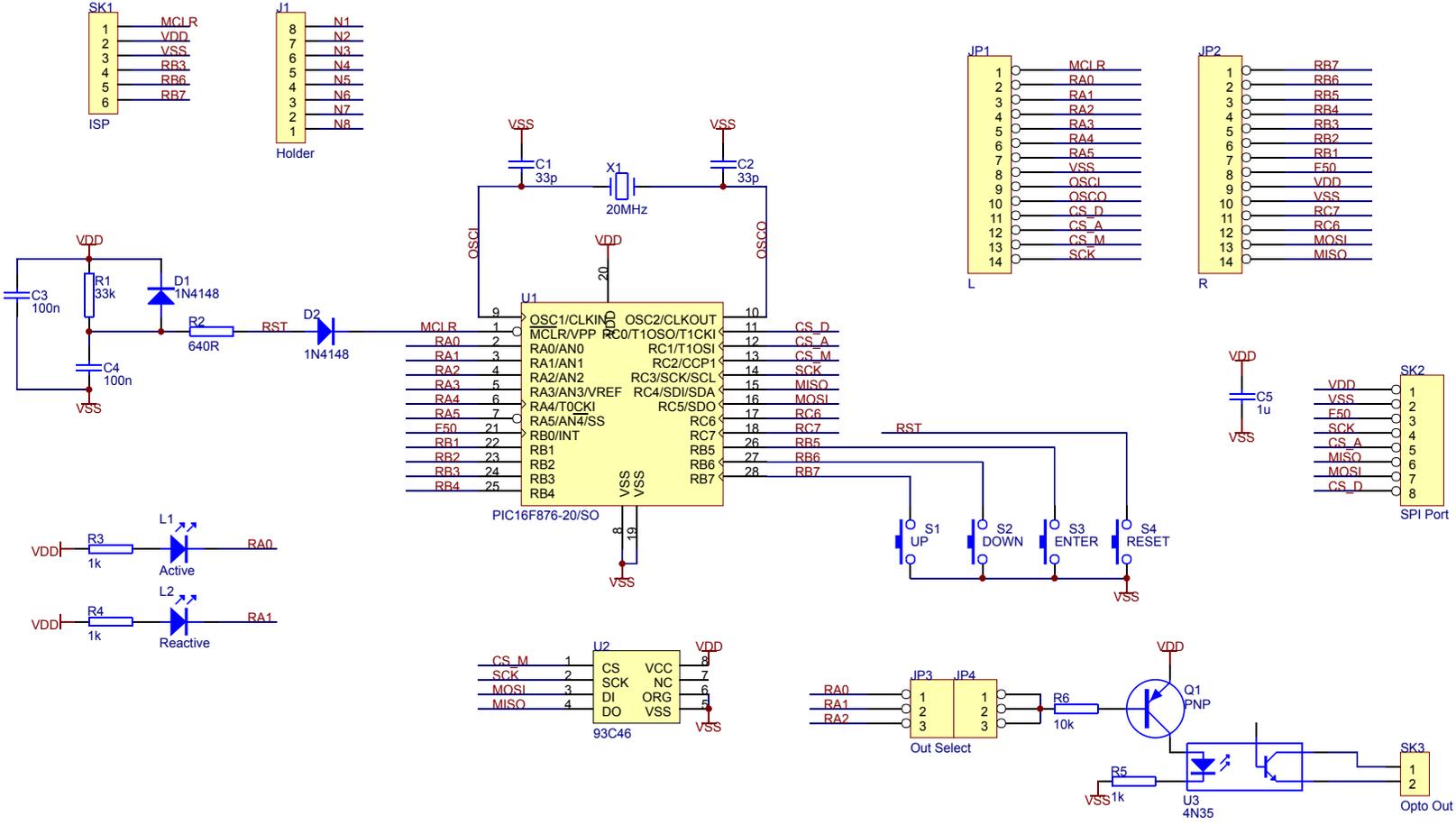


Figure 21: Micro-Controller Board Schematic



MICRO-CONTROLLER BOARD

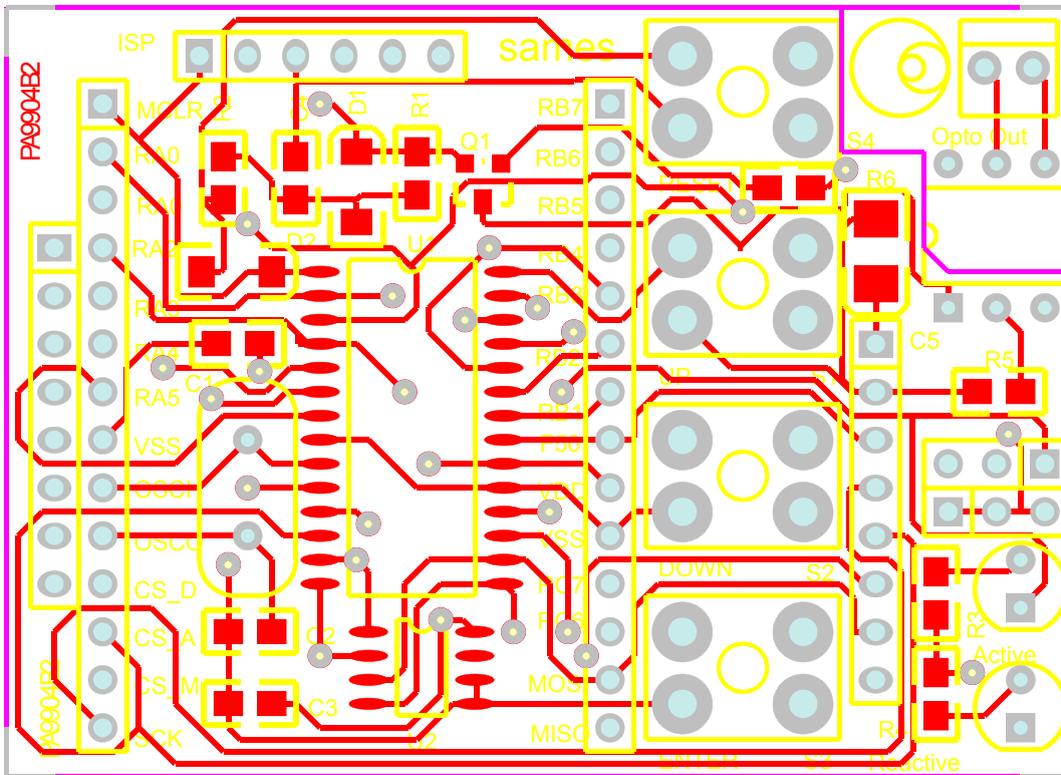


Figure 22: Top PCB layout

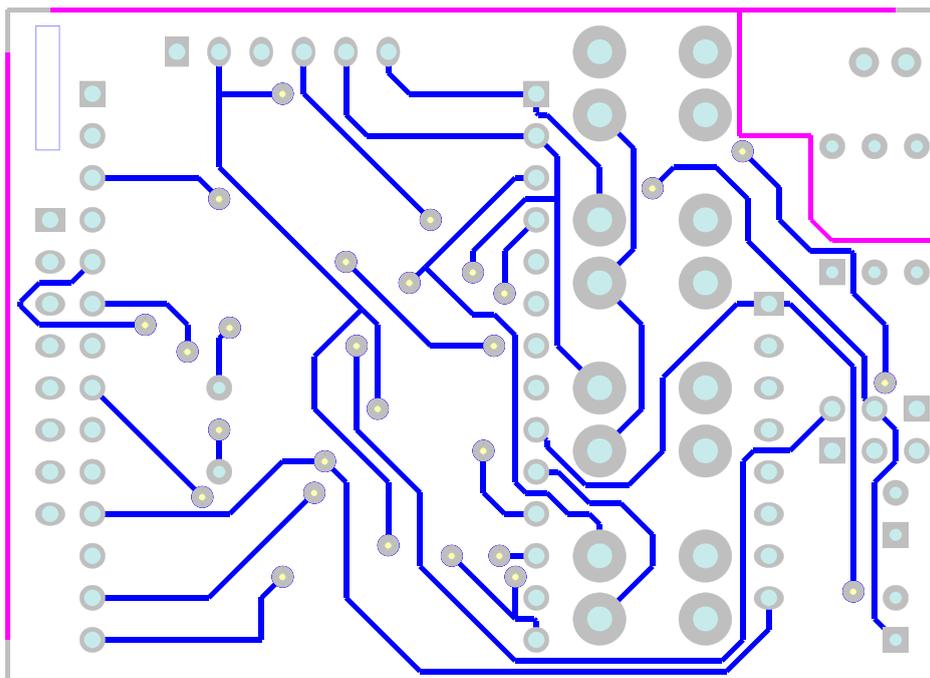


Figure 23: Bottom PCB layout

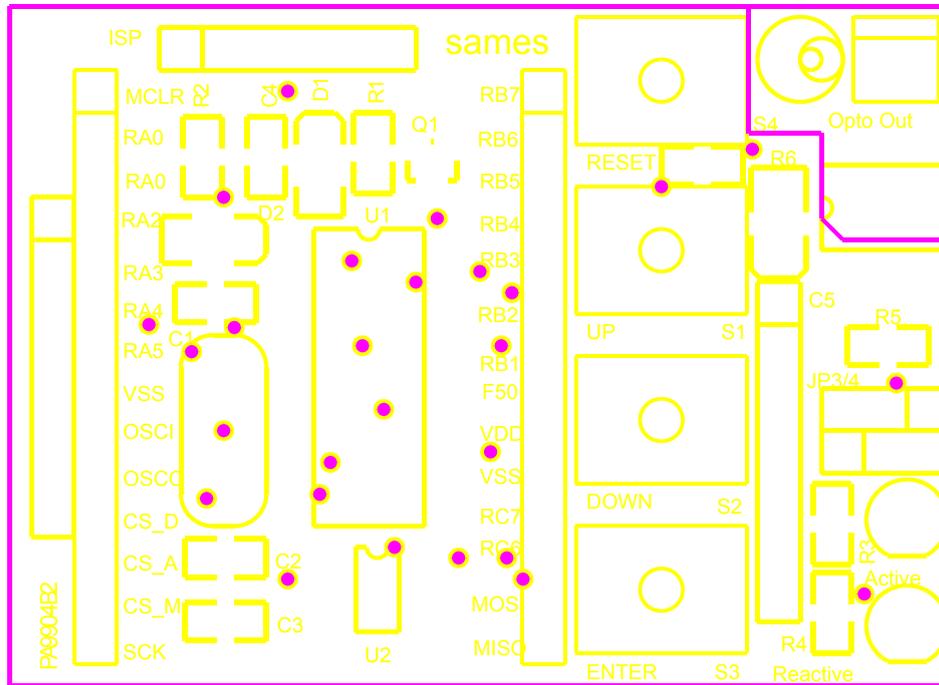


Figure 24: Silkscreen PCB layout (Micro-controller board)

**COMPONENT LIST (Micro-controller board)**

Designator	Part Type	Footprint	Description
D1	1N4148	MELF-MINI-D	Si signal diode
D2	1N4148	MELF-MINI-D	Si signal diode
R5	1k	805	Resistor, 1%
R4	1k	805	Resistor, 1%
R3	1k	805	Resistor, 1%
C5	1u	3528	Capacitor, tantalum/10V
U3	4N35	DIP6	Opto-coupler, medium speed
R6	10k	805	Resistor, 1%
X1	20MHz	XTAL3	Crystal
R1	33k	805	Resistor, 1%
C2	33p	805	Capacitor, ceramic
C1	33p	805	Capacitor, ceramic
U2	93C46	SO-8	e ² prom, 1kB
C3	100n	805	Capacitor, ceramic
C4	100n	805	Capacitor, ceramic
R2	100R....1kΩ	805	Resistor, 1%
L1	Active	LED3MM	3mm green
S2	DOWN	SW_PB_SMALL	Micro switch, push to make
S3	ENTER	SW_PB_SMALL	Micro switch, push to make
JP4	HEADER 3	SIP3	3 pin SIP pins
J1	Holder	SIP8	8 pin SIP socket
SK1	ISP	SIP6	6 pin SIP pins
JP1	L	SIP14	14 pin SIP pins
SK3	Opto Out	2PIN_MOLEX	2 Pin Molex, Centre square pin, Friction lock
JP3	Out Select	SIP3	3 pin SIP pins
U1	PIC 16F876-20/SO	SOL-28	Micro-controller
Q1	PNP	SOT-23	Any Si PNP, e.g. SMBT3906
JP2	R	SIP14	14 pin SIP pins
S4	RESET	SW_PB_SMALL	Micro switch, push to make
L2	Reactive	LED3MM	3mm red
SK2	SPI Port	SIP8	8 pin SIP socket
S1	UP	SW_PB_SMALL	Micro switch, push to make



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PM9904BPD

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