Technical Manual

for

SBC488/OEM

Single Board Computer
with the IEEE 488 Interface

by

TIDAL

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     Rev. A
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Forward

The SBC488/OEM technical manual covers the operation and maintenance for the SBC488. There also is another version of the SBC488 called the SBC488/TEST that supports the board in test applications. In test applications, the SBC488 acts as a test controller and is used to create small to medium sized automated test systems. The SBC488/TEST manual covers both operation, maintenance and software development.

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SAFETY

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┌─────────────────────────────────────────────────────────────────────┐
│                            WARNING                                    │
│ High voltage AC and DC exist on the SBC488 printed circuit            │
│ board.  Do not touch the unit with power on.  Failure to observe      │
│ this warning could result in serious injury or death.                 │
└─────────────────────────────────────────────────────────────────────┘
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1.0 OVERVIEW

The SBC488 is a single board computer that incorporates a variety of input and output capabilities beginning with two communication interfaces.

The SBC488 gets its name from the IEEE 488 bus which is also known as the General Purpose Interface Bus (GPIB). The IEEE 488 bus allows up to 15 instruments within a localized area to communicate with each other. Data is sent through the bus in parallel a byte (8 bits) at a time. The data consists of device dependent (commands specific to the SBC488) and generic interface messages (commands common to all IEEE 488 devices). Each device is assigned and responds to a unique address. The address is set by a five position address dipswitch that is read by the SBC488 at power up.

The SBC488 implements only the Talker/Listener functions defined by the IEEE 488 standard. The SBC488 therefore, acts as a slave to the bus controller. It responds to data request commands and setpoint commands. Another SBC488 model, the SBC488/TEST can perform talker/listener and IEEE 488 bus controller functions and is used to control small to medium sized automated test systems. See Figure 1, the SBC488 block diagram.

In addition to the IEEE 488 interface the SBC488 also supports RS-232 communications at 9600 Baud. The RS-232 interface is an asynchronous serial interface. Commands are received and data is sent by the SBC488 over the RS-232 interface. Either the IEEE 488 or the RS-232 interface can control the SBC488. This provides the end user with the flexibility of multiple communication options.

The optional analog input on the SBC488 consists of an eleven channel, 12 bit Analog to Digital Converter (ADC). The ADC is isolated from the MicroProcessor Unit (MPU) and the communication interfaces with high speed opto-isolators affording a 2500 VAC isolation barrier.

The optional analog output on the SBC488 consists of four, 12 bit Digital to Analog Converters (DAC). The DACs are also isolated from the MPU and the communication interfaces.

The SBC488's optional digital I/O is capable of 32 bits of bi-directional input and output. The optional four 8 bit ports are also optically isolated.

The SBC488 incorporates an MPU module from Z-World Engineering called a SmartCore. The SmartCore features a Z180 MPU running at 9.216 Mhz.
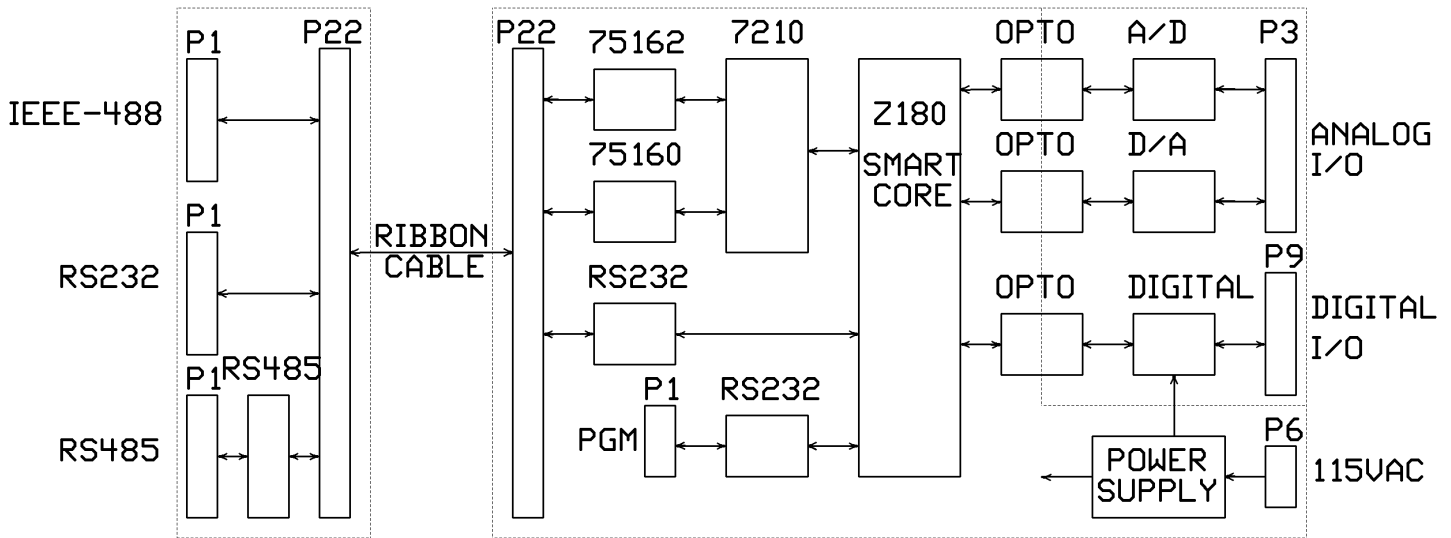
Figure 1, SBC488 Block Diagram

The SBC488 supports software development using the optional Dynamic C environment available from Z-World Engineering. With the software development option and Dynamic C, a programmer can make modifications to the generic firmware of the SBC488. This allows changes to the standard command set and the incorporation of additional commands. The software development option includes a 128K EPROM with the Dynamic C monitor installed.

1.1 Part Number Breakdown

The part number for the SBC488/OEM determines the installed options. The part number is created as follows:

SBC488/OEM	-xDA	x.xx	-ADx.x	-xDIG	-DEV
Model number	no. of DAC channels	DAC Option voltage reference	ADC Option voltage reference	No. of Digital Ports	Software Develop. Option
SBC488/OEM	blank	blank	blank	blank	blank
	-1DA	2.50	-AD2.50	-1DIG	-DEV
	-2DA	4.10	-AD4.10	-2DIG	
	-3DA	5.00	-AD5.00	-3DIG	
	-4DA	8.20	-AD8.20	-4DIG	
	-5DA	10.0	-AD10.0		
	-6DA				

Part number example:

SBC488/OEM-4DA2.50-AD2.50-3DIG

This part number is for an SBC488 single board computer with the OEM firmware and the following hardware options:
- Four DACs with a 0-2.5 VDC full scale range.
- Eleven channel ADC with a 0-2.5 VDC full scale range.
- Three digital I/O ports, 8 bits each for a total of 24 I/O.

2.0 Specifications

2.1 The IEEE 488 Interface

```
Specification: IEEE 488.1 and IEEE 488.2 (partial)
Controller: NEC uPD7210 or National Instruments 7210
Controller Clock: 8 Mhz
Transceivers: 75160 and 75162 (Texas Instruments)
Address Capability: 0 to 30
SRQ generation: ESE,SRE masks (See section 5, programming)
```

2.2 RS-232 Interface

```
RS-232 Communications
Baud Rate: 9600 Baud
Data Size: 8 bit
Parity:    None
Stop bits: 1
Connector Configuration: 9 Pin D-Sub, IBM Pinout
```

2.3 Optional Analog to Digital Converter (ADC) Specifications

Parameter	
Channels	11
Resolution	12 bit
ADC P/N	TLC2543
Linearity Error	+/-1 LSB max.
Gain Error	+/-1 LSB max.
Offset Error	+/-1.5 LSB max.

```
Voltage Reference
```

Parameter	
Reference Voltage Options	2.50, 4.1 and 5.0 VDC
Reference P/N	LM4040-x
Reference Accuracy	+/- 0.5% max.
Temperature Coeff.	+/- 100 ppm/°C

```
Isolation: 2500 VAC (Between CPU and I/O)
```

2.4 Optional Digital to Analog Converter (DAC) Specifications

Parameter	
Channels	6 Max.
Resolution	12 bits
DAC P/N	LTC1257
Offset Error	+/-5mV max.
Total Error	+/-2 LSB max.
Output Impedance	300 ohm max.
Rated load	2 ma ||100pf
Temperature Coeff.	+/- 0.02 LSB/°C max.

Voltage Reference

Parameter	
Reference Voltage	2.50, 4.1, 5.0, 8.2 and 10.0 VDC
Reference P/N	LM4040-x
Reference Accuracy	+/- 0.5% max.
Temperature Coeff.	+/- 100 ppm/°C

Isolation: 2500 VAC (Between CPU and I/O)

2.5 Optional Digital Input/Output (I/O) Specifications

Parameter	
Maximum number of ports	4 eight bit ports (24 bits total)
Type	Quasi Bi-directional
Port P/N	Phillips PCF8574
Output Voltage	5.0 VDC typical.
Input Voltage Range	-0.5 to 5.5 VDC
Output Current Low	10 ma Min.
Output Current High	30 uA Min
Input Voltage Low	1.5 VDC Max.
Input Voltage High	3.5 VDC Min

Isolation: 2500 VAC (Between CPU and I/O)

2.6 SmartCore(tm) Specifications

The SBC488 incorporates an MPU module from Z-World Engineering that provides a compact and powerful central processor core module (Figure 2, SmartCore block diagram). The SmartCore(tm) features:

- Z180 CPU running at 9.216 Mhz.
- Static Ram (SRAM), 32K to 128K for data storage (with optional battery backup).
- Erasable Programmable Read Only Memory (EPROM), 32K to 128K for program storage.
- Electrically Erasable PROM (EEPROM), 512 bytes, for non-volatile storage without a battery.
- Real-Time Clock (RTC), for time calculations.
- Reset and power failure supervisor to provide reset to the MPU if power is out of range and to switch in the battery back-up if there is a battery installed.
- Serial interface for program development option, Port 1.
- Serial interface for the application, Port 0.
- Two programmable timers used as interval timers.
- Two Direct Memory Access (DMA) channels for high speed transfers to internal serial ports and external I/O.
- Memory decoding for external devices (/CS1-/CS6).
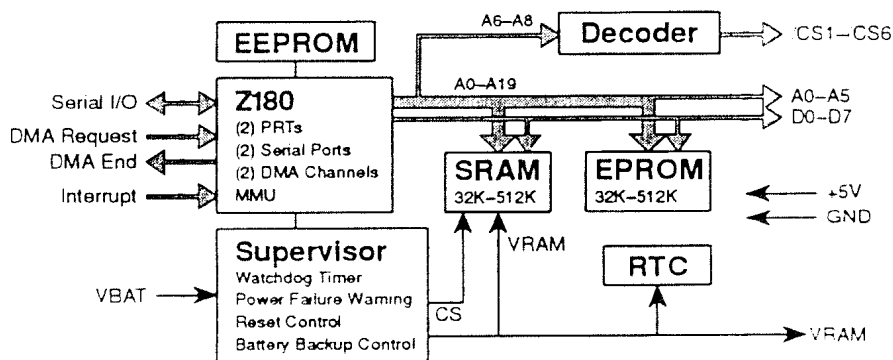
Figure 2, SmartCore Block Diagram

2.7 Indicators and Controls

a.   Address switch
     The IEEE 488 address is programmed via the 5 position dip switch
     on the rear of the SBC488. The address is configured as
     follows:
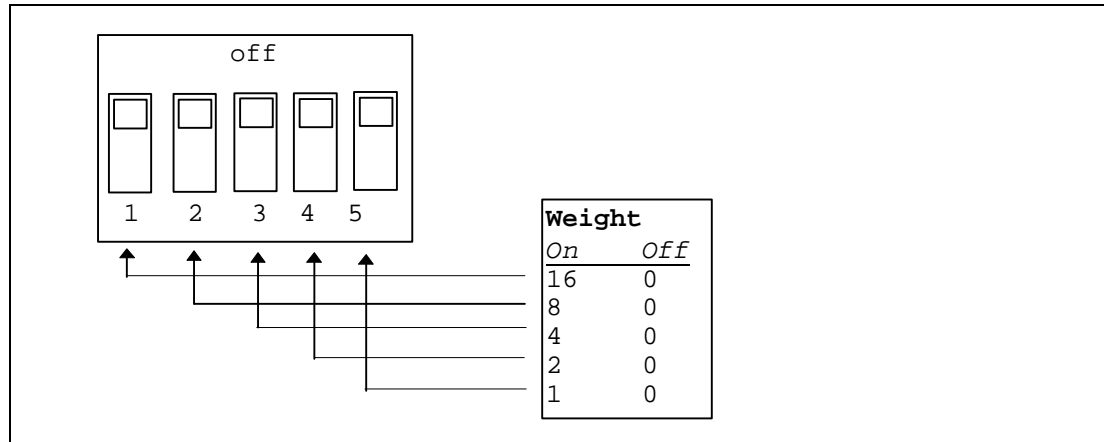
Figure 3, IEEE 488 Address Switch

     Note: Cycle SBC488 power after changing dip switch setting.

b.   Indicator Lights

     The SBC488 uses five indicator lights to indicate the status of
     the communication channel. The IEEE 488 interface and RS-232
     interface share the indicator lights. The light's functions are
     similar for both communication channels.
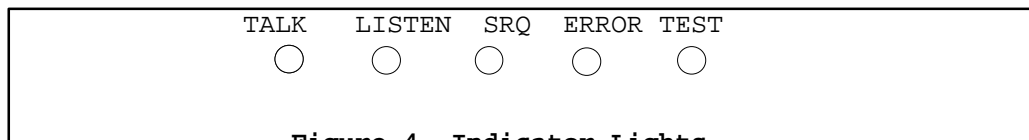
Figure 4, Indicator Lights

Indicator light functions for IEEE 488 communications

Indicator	Function
TALK	This light indicates that the IEEE 488 bus has requested data from the SBC488 and that the data is being sent.
LISTEN	This light indicates that IEEE 488 bus has put the SBC488 in the listen mode by sending it's listen address.
SRQ	The SRQ or Service Request light indicates that a condition has occurred in the SBC488 that requires service. The logic of SRQ generation is programmable over the IEEE 488 and is explained in section 5.2.
ERROR	This light is lit when a command error occurs. The light will go out when the next valid command is received.
TEST	This light is not used in this version

Indicator light functions for RS-232 communications

Indicator	Function
TALK	This light indicates that the RS-232 bus has requested data from the SBC488 and that the data is being sent.
LISTEN	This light indicates that RS-232 bus is sending data to the SBC488.
SRQ	This light is not used.
ERROR	This light is lit when a command error occurs. The light will go out when the next valid command is received.
TEST	This light is not used.

2.8 Pin Descriptions

a. P1 IEEE 488 Connector

Pin	Name/Description	Pin	Name/Description
1	DIO1/Data line	13	DIO5/Data line
2	DIO2/Data line	14	DIO6/Data line
3	DIO3/Data line	15	DIO7/Data line
4	DIO4/Data line	16	DIO8/Data line
5	EOI/End or Identify	17	REN/Remote Enable
6	DAV/Data Valid	18	DAV Gnd
7	NRFD/Not Ready For Data	19	NRFD Gnd
8	NDAC/Not Data Accepted	20	NDAC Gnd
9	IFC/Interface Clear	21	IFC Gnd
10	SRQ/Service Request	22	SRQ Gnd
11	ATN/Attention	23	ATN Gnd
12	Shield	24	Ground

b. P3 DAC and ADC Connector

Pin	I/O	Name/Description	Voltage Level
1	O	CH0/Channel 0 output	0 to DAC VREF*4095/4096
2	O	CH1/Channel 1 output	0 to DAC VREF*4095/4096
3	O	CH2/Channel 2 output	0 to DAC VREF*4095/4096
4	O	CH3/Channel 3 output	0 to DAC VREF*4095/4096
5	O	CH4/Channel 3 output	0 to DAC VREF*4095/4096
6	O	CH5/Channel 3 output	0 to DAC VREF*4095/4096
23	I	CH0/Channel 0 input	0 to ADC VREF*4095/4096
25	I	CH1/Channel 1 input	0 to ADC VREF*4095/4096
26	I	CH2/Channel 2 input	0 to ADC VREF*4095/4096
21	I	CH3/Channel 3 input	0 to ADC VREF*4095/4096
19	I	CH4/Channel 4 input	0 to ADC VREF*4095/4096
17	I	CH5/Channel 5 input	0 to ADC VREF*4095/4096
15	I	CH6/Channel 6 input	0 to ADC VREF*4095/4096
22	I	CH7/Channel 7 input	0 to ADC VREF*4095/4096
11	I	CH8/Channel 8 input	0 to ADC VREF*4095/4096
13	I	CH9/Channel 9 input	0 to ADC VREF*4095/4096
18	I	CH10/Channel 10 input	0 to ADC VREF*4095/4096
10	I	Ground	Reference

c. P4 RS-232 Interface Connector

Pin	I/O	Name/Description	Voltage Level
1	I	Gnd	Reference
2	I	RX/Receive Data	-8 to +8 VDC
3	O	TX/Transmit Data	-8 to +8 VDC
4	I	CTS/Clear to Send	-8 to +8 VDC
5	O	RTS/Request to Send	-8 to +8 VDC
7	I	Gnd	Ref

```
+------------------------------------------------------------------+
|                            WARNING                               |
| High voltage AC and DC exist on the SBC488.  Do not touch the unit|
| with power on.  Failure to observe this warning could result in  |
| serious injury or death.                                         |
+------------------------------------------------------------------+
```

d. P6 Power

Pin	Name/Description
1	120 VAC +/- 20%
2	GND
3	120 VAC +/- 20%

g. P9 Digital I/O Connector

Pin	I/O	Name/Description	Voltage Level
1	O	+5 VDC Power	+5 VDC
2	I/O	D1-LSB Data 0 I/O	+5 VDC
3	I/O	D1 Data 1 I/O	+5 VDC
•	•	•	•
•	•	•	•
10	I/O	D2-LSB Data 0 I/O	+5 VDC
11	I/O	D2- Data 1 I/O	+5 VDC
•	•	•	•
•	•	•	•
18	I/O	D3-LSB Data 0 I/O	+5 VDC
19	I/O	D3 Data 1 I/O	+5 VDC
•	•	•	•
•	•	•	•
26	I/O	D4-LSB Data 0 I/O	+5 VDC
27	I/O	D4- Data 1 I/O	+5 VDC
•	•	•	•
•	•	•	•
34	O	Power Return	0 VDC

2.9 Physical Description

```
Dimensions:            5.0" x 9.0" (127mm x 229mm)
Weight:                0.74 lb. (330 gm)
Power Requirements:    120 VAC +/- 20%, 6 VA, 4 W
Operating temperature: 0 to 70 °C.
```

3.0 Functional Description

3.1 IEEE 488 Interface

The IEEE 488 bus, originally developed by Hewlett Packard, is designed to connect test equipment to computers and computer peripherals. It allows up to 15 devices within a localized area to communicate with each other. Data is sent by one device (the talker) and received by any number of listeners. The bus controller sends commands to the devices on the bus. The talker/listener devices can send data and receive data and commands.

Each device has a unique address that it responds to. The address of a device is usually set by a group of dip switches on the device that are read at power up.

The interface consists of eight data lines (DIO0-DIO8) and eight handshake/control lines. The handshaking lines are DAV, NRFD, NDAC. The control lines are IFC, ATN, SRQ, REN and EOI.

The DAta Valid (DAV) line tells the recipient of the data that it is valid. The Not Ready For Data (NRFD) line tells the sender that at least one device is not ready for data. The NDAC line tells the sender that at least one device has not accepted the data.

The bus controller uses the ATN line to tell the devices on the bus that it is sending a command. When the ATN line is true, all devices listen for the command coming over the bus. When the ATN is false, only addressed devices will participate.

The Service ReQuest line (SRQ) allows any device on the bus to request service and "interrupt" the controller.

The End Or Identify line (EOI) can be asserted by the talker when the last data byte has been put on the bus. This is optional and is set up in the IEEE 488 bus controller. The SBC488 requires that the EOI is asserted during the last byte of a data transfer.

The IEEE 488 interface in the SBC488 is managed by an NEC uPD7210 type Application Specific Integrated Circuit (ASIC). The IEEE 488 Integrated Circuit (IC), U81 is connected to the SmartCore's 8 bit data bus (See Figure 5). In addition, U81 is connected to the least significant three bits of the address bus. These address lines are used by the CPU to address the eight read and write registers that control the U81's operation. Also, U81 connects to the SmartCore's /CS1, /IORD, /IOWR and /INT1 lines. Note that the "/" before the signal name means that the signal is active low.

The Chip Select 1 (/CS1) signal is an active low signal that tells the IEEE 488 IC that it is being addressed.

The Input Output ReaD (/IORD) line is an active low signal that tells
the IEEE 488 IC that the MicroProcessor Unit (MPU) is reading data
from one of it's eight registers. The IEEE 488 IC then enables its
data bus drivers and puts the data from the selected register on the
bus.

The Input Output WRite (/IOWR) line is an active low signal that
tells the IEEE 488 IC that the MPU is writing data to it. The IEEE
488 IC then reads the data bus and stores the data in the register
selected by the three address lines.

U81 also requires an external clock that is provided by an 8 Mhz CMOS
oscillator IC, U110.

The IEEE 488 IC (U81) is interfaced to the IEEE 488 bus through two
application specific GPIB transceivers U82 (75160) and U83 (75162).
The data transceiver (U82) is a bi-directional high speed tristate
driver/receiver. The control transceiver (U83) serves as the
interface to the control lines (DAV, NRFD, NDAC, IFC, ATN, SRQ, REN,
EOI). U83 has both tristate drivers and open collector drivers as
determined by the IEEE 488 standard.

The IEEE 488 interface connector, P1 is a shielded connector
specifically designed for the IEEE 488 bus.

The interface between the SmartCore and U81 is interrupt driven.
That is, once U81 is programmed at initialization, it is only
serviced when data is received or requested by the bus. The U81
interrupt line, U81-11, which is normally low, will go high after the
communication begins on the bus and low after the MPU services the
interrupt and reads the appropriate register. The SmartCore /INT1
(U100-21) pin is used for this signal.

The IEEE 488 address is programmed by DSW1 (See figure 5) and defined
by the IEEE standard to be between 0 and 30. The SBC488 interprets
an address of 31 to mean that RS-232 control is being used. The data
buffer/input port U71 (74HC541) allows the MPU to read the address
set on the switch. The MPU then programs U81 at power up for that
device address.
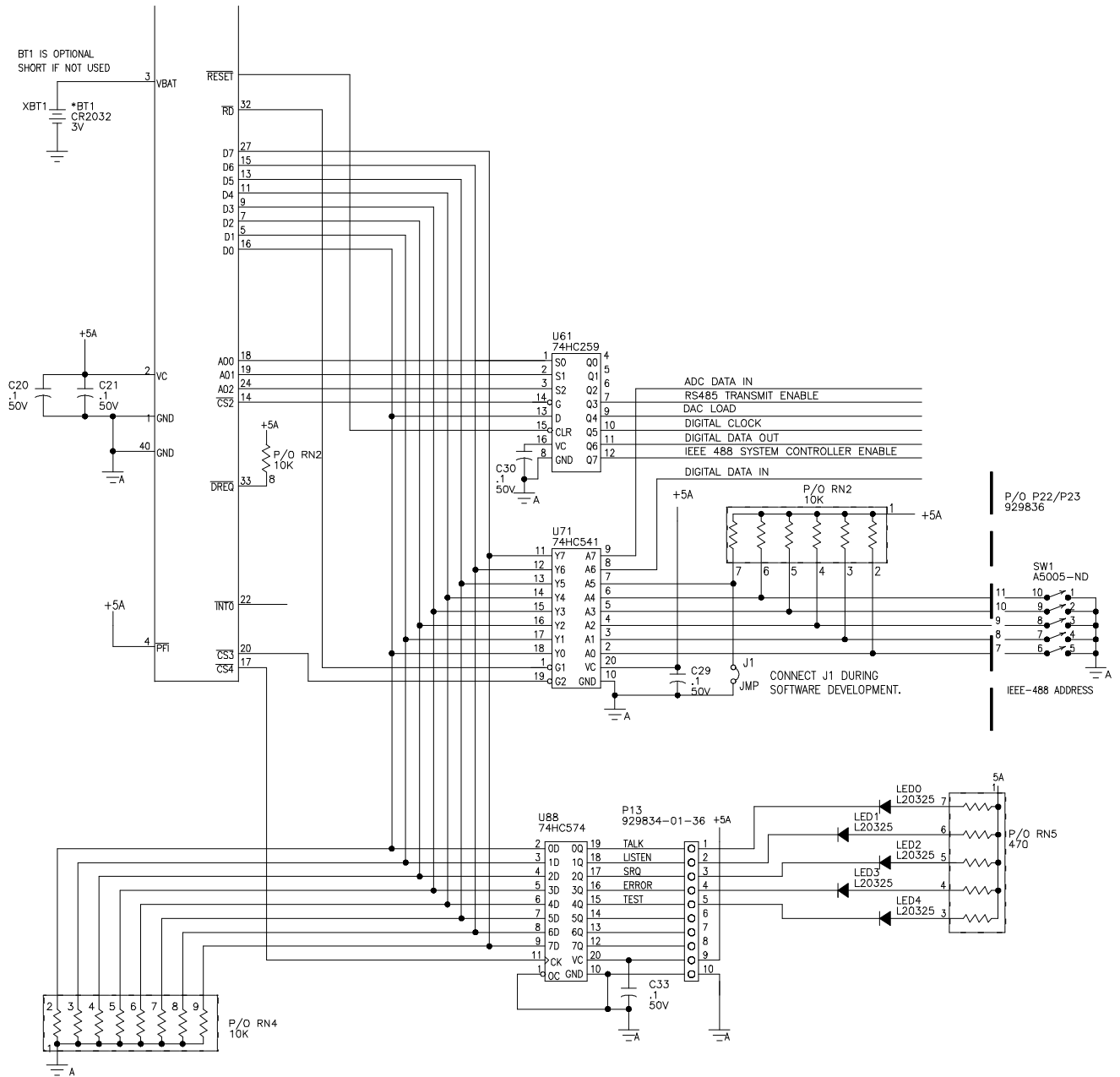
Figure 5, Miscellaneous Control Schematic

3.2 RS-232 Interface

In addition to the IEEE 488 interface the SBC488 also supports RS-232 communications at 9600 Baud.

The Z180 Microprocessor has two integrated UART (Universal Asynchronous Receiver/Transmitter) ports, 0 and 1. The UART channel 0 is used by the SBC488 application. The channel 1 UART is used for software development with the -DEV option. The UART signals are passed through the RS-232 transceiver U85 (See Figure 6). U85 has an onboard charge pump circuit to generate the +/- 9 volts required by

the RS-232 interface. The RS-232 UART port is interrupt driven and generates an internal interrupt when it requires attention.

The RS-232 interface connects externally through a 9 Pin D-Sub-miniature connector (P4) PCB mounted on the SBC488. Note that the CTS signal (RTS at the IBM) should be driven true to enable communications.
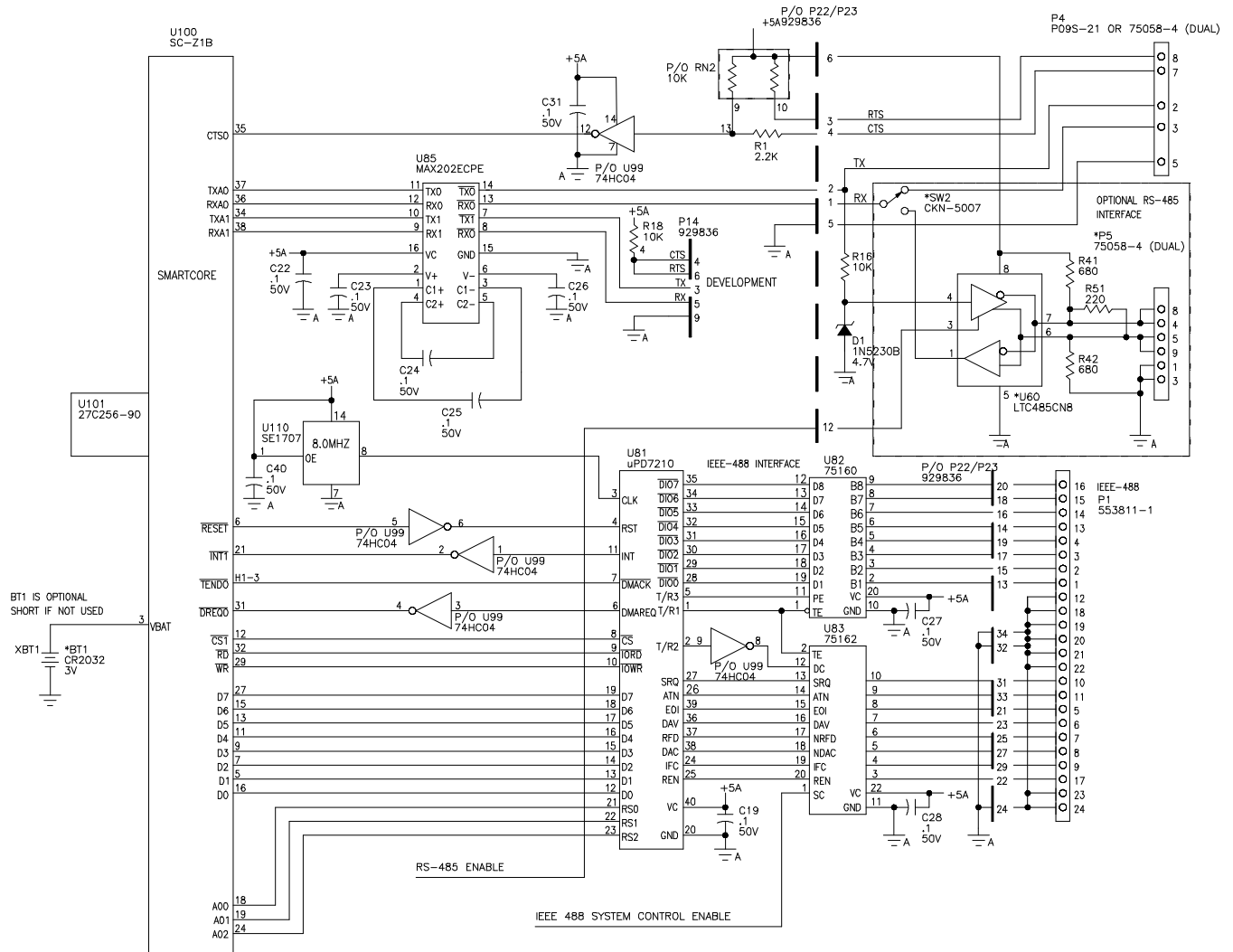
Figure 6, IEEE 488 and RS-232 Interface Schematics

3.3 Optional Analog to Digital Converter (ADC)

The analog input on the SBC488 consists of an eleven channel, 12 bit ADC. The ADC is isolated from the MPU and the communication interfaces with high speed opto-isolators affording a 2500 VAC isolation barrier.

The ADC IC, U90, interfaces via a four wire serial interface that simplifies optical isolation. The interface signals consist of:

    a. Serial Clock (U90-18)

    b. Chip Select (U90-15)
    c. Data Out (U90-16)
    d. Data In (U90-17)

These digital signals are manipulated by the MPU via the 8 bit
addressable latch, U61 and are isolated by U41 opto-isolator (See
Figure 5). The Data Out pin of the ADC is isolated by U44 opto-
isolator and is read by the 8 bit input port.

The ADC reference inputs are provided by a precision voltage
reference U22. The ADC converter's full scale voltage can be changed
to 2.5, 4.096 or 5.0 VDC by substituting the appropriate version of
U22. Note that the ADC reference can only accept 5.0 VDC max.
whereas the DACs can accept up to 10 VDC.   The ADC inputs can accept
higher voltages, however, by configuring a voltage divider with RN9-
RN11 and optional RN31.

The ADC's analog inputs are protected by diode clamps to +5 VDC and
ground and by input resistor networks RN9-RN11. The input resistors
in conjunction with capacitor networks CN1 and CN2 provide a low pass
filter to reduce input noise on the ADC.
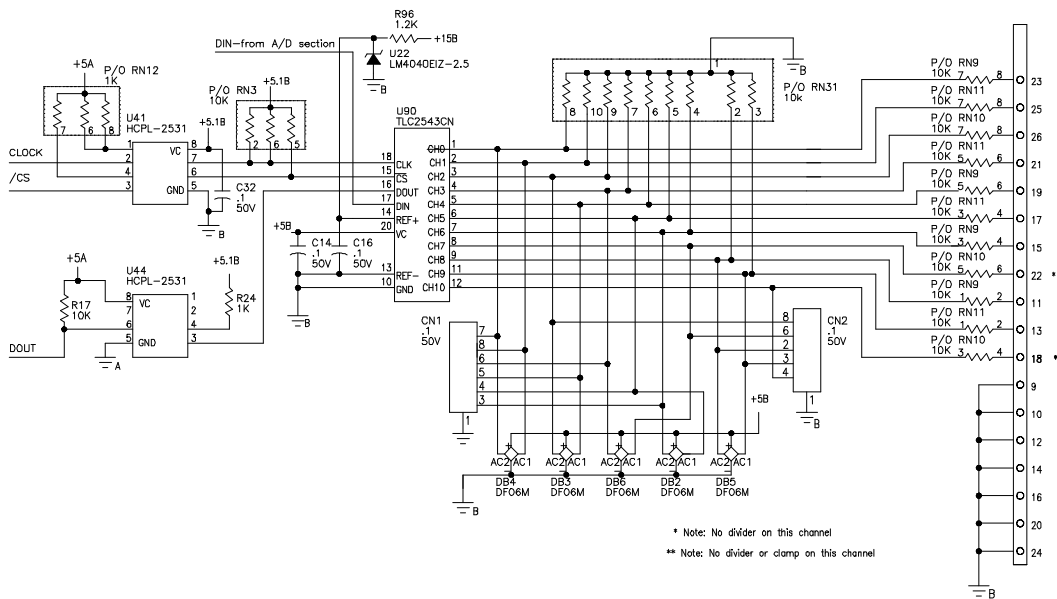
Figure 7, Analog to Digital Converter Schematic

3.4 Optional Digital to Analog Converter (DAC)

The analog output on the SBC488 consists of up to six 12 bit DACs.
The DACs are isolated from the MPU and the communication interfaces.

The DAC ICs, U11-U16, interface via a four wire serial interface.
The interface signals consist of:

    a. Serial Clock (U11-1)
    b. Load DAC (U11-3)
    c. Serial Data In (U11-2)

d. Serial Data Out (U11-4)

These digital signals are manipulated by the MPU via the 8 bit
addressable latch, U61 and are isolated by U42 opto-isolator.

The DAC reference inputs are provided by U21.

The DAC's analog outputs are protected by an output resistor network,
RN8.
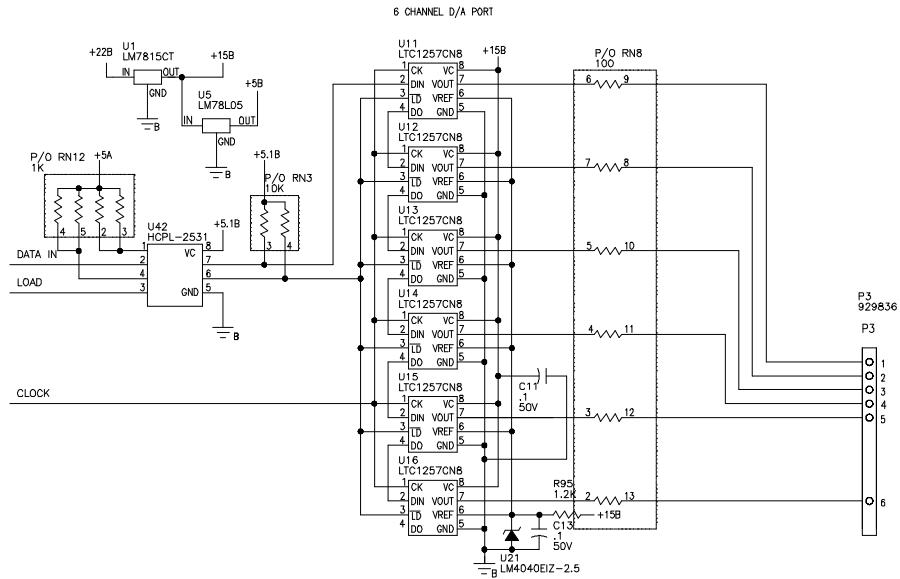
Figure 8, Digital to Analog Converter Schematic

3.5 Optional Digital Input/Output (I/O)

The SBC488's optional digital I/O provides up to 32 bits of bi-directional digital I/O. The four 8 bit ports are isolated from the MPU and the communication interfaces with high speed opto-isolators affording a 2500 VAC isolation barrier.

The digital I/O port IC's, U51-U53, are remote 8 bit I/O expanders for the I^{2}C bus. Their I^{2}C interface is a two wire serial interface. (See Figure 9, Digital I/O)

The interface signals consist of:

        a. Serial Clock SCL (U51-14)
        b. Serial Data SDA (U51-15)

The I^{2}C interface incorporates a serial addressing method whereby data is written to or read from a specific port among up to eight ports that are connected on the I^{2}C bus. The port address is configured by three pins on each chip, A0 (Pin 1), A1 (Pin 2) and A2 (Pin 3). These three address pins allow up to eight devices to be individually identified on the same serial bus. In the SBC488, U51 is at address 0, U52 is at address 1 , U53 is at address 2 and U54 is at address 3.

Each pin on these ports can sink up to 10 ma and source up to 30 uA. Additional source current can be provided by the optional pull-up resistor networks RN21 thru RN24. The ports are quasi bi-directional which means they can be used as inputs or outputs. The MPU can read any pin by first setting the port to high, which engages a high impedance pull-up and then reading the pin.

These chips also provide an interrupt output that occurs on any input pin change. This feature is not used in the SBC488 firmware though it is wired up for future use.

The digital signals, SDA and SCL are manipulated by the MPU via the 8 bit addressable latch, U61 and are isolated by opto-isolator U47 (See Figures 5 and 9). The interrupt and read data are isolated by U48 opto-isolator. The read data is connected to 8 bit input port U71. The interrupt signal connects to /INT0 (U100-22) on the SmartCore.
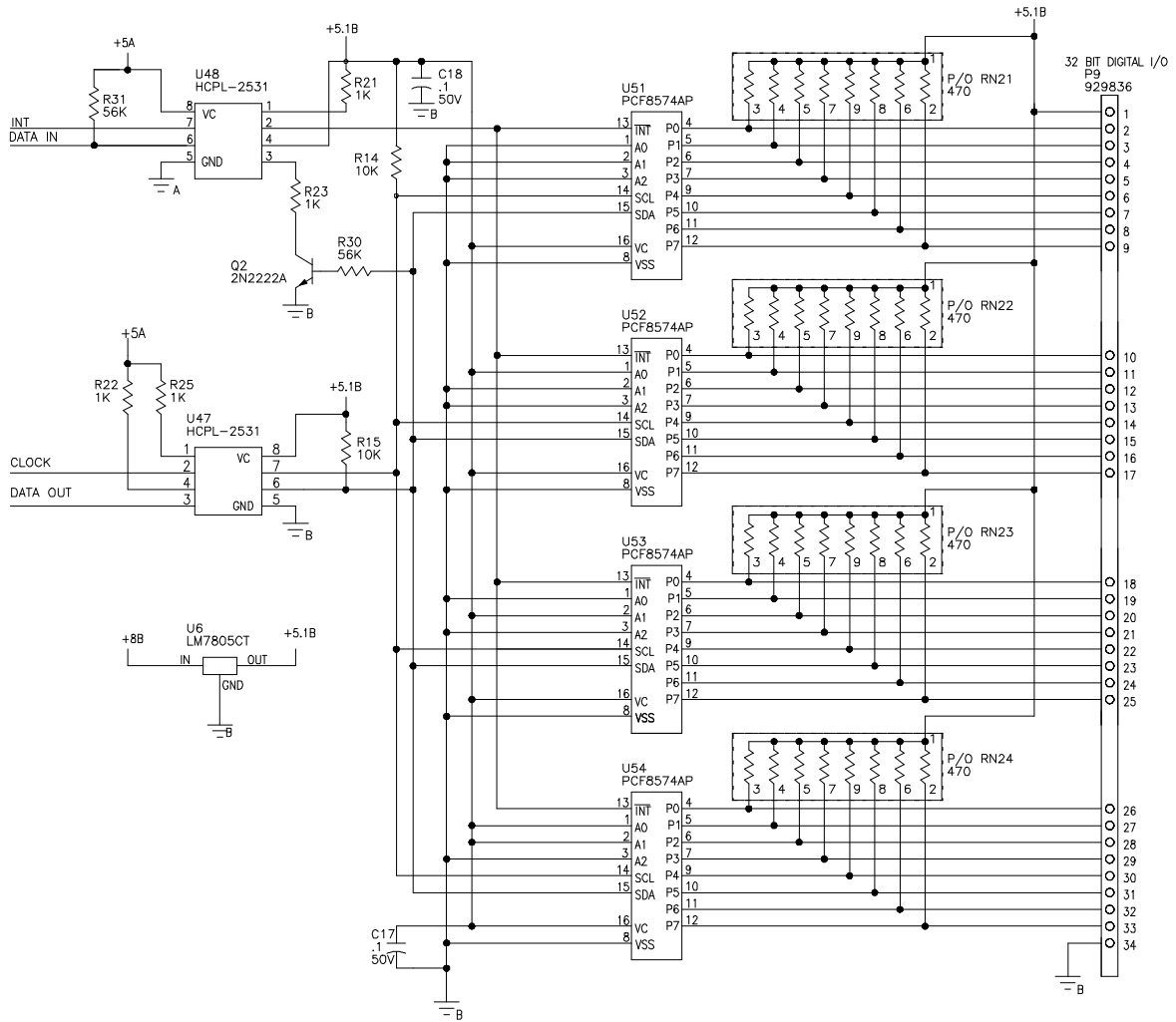
Figure 9, Digital I/O

3.6 Smart Core Features

The SmartCore(tm) features a Z180 CPU running at 9.216 Mhz. (Figure 10, SmartCore block diagram).

The SmartCore onboard memory consists of:

    a. SRAM, 32K (128K for -DEV option) Battery backup optional.
    b. EPROM, 32K (128K for -DEV option)
    c. EEPROM, 512 bytes.

Other SmartCore peripherals are:

    d. Real-Time Clock
    e. Reset and Power Failure Supervisor.
    f. Serial Interface for program development.
    g. Serial Interface for the application.

       h.   Two programmable timers.
       i.   Two DMA channels.
       j.   Memory decoding for external devices (/CS1-/CS6).
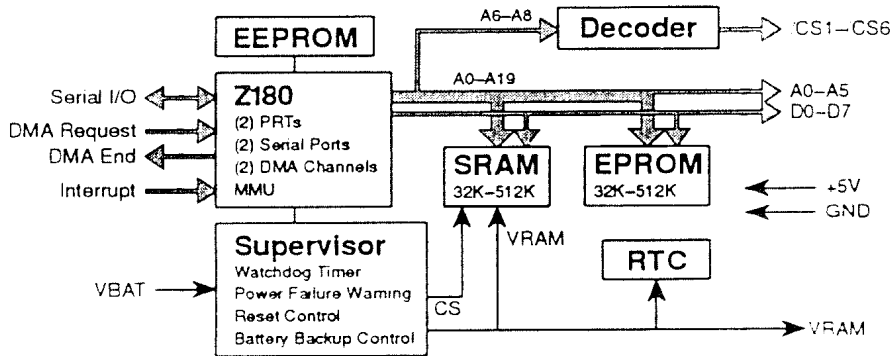
Figure 10, SmartCore Block Diagram

3.7 Power Supply Features

The SBC488 features an off line switching power supply. The power
supply provides power to the computer interface circuitry and to the
I/O sections. The schematic for the power supply is included as
figure 11 below.

The power supply features:
- 2500 VAC isolation
- 3 outputs +5,+5 and +15 VDC
- EMI suppression
- Overload Protection
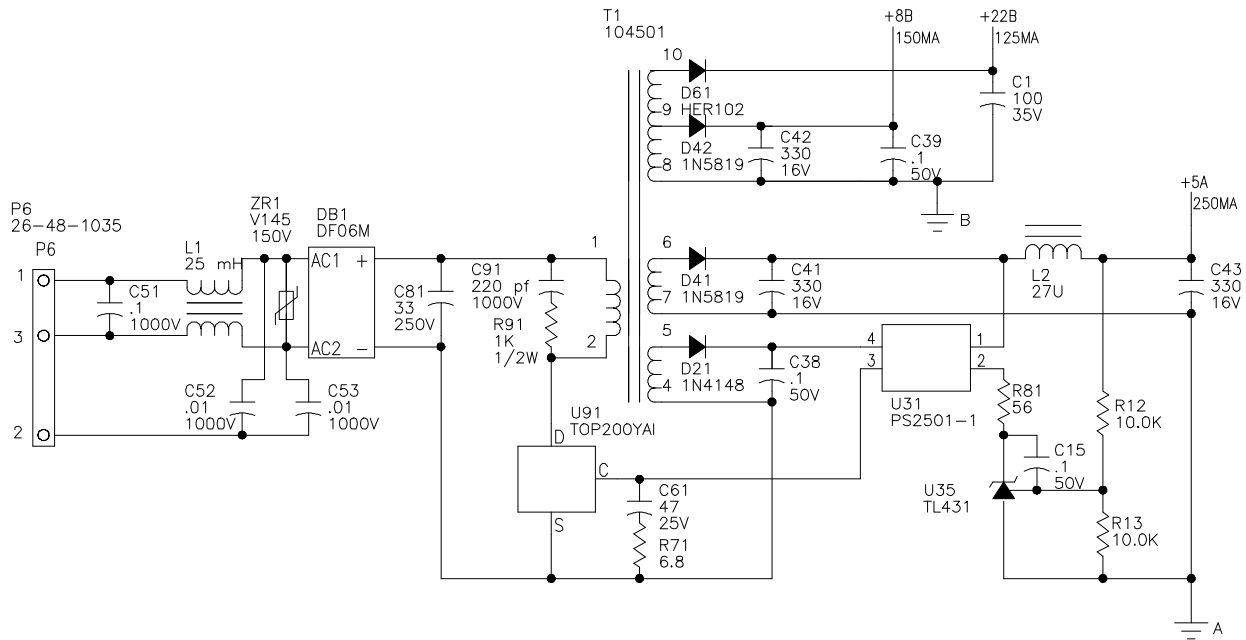
Figure 11, SBC488 Power Supply Diagram

4.0 Operating Instructions

4.1 Unpacking
Call the carrier immediately upon receipt if the shipping carton is damaged. Then inspect the SBC488 for damaged or loose components. If there is any damage contact your sales agent to obtain Return Material Authorization (RMA).

4.2 Setup and Configuration
The SBC488 is ready to operate without any calibration or software setup. To test the SBC488's optional ADC and DAC functionality on the bench the analog inputs can be looped back to the analog outputs. This test procedure is described in 4.3 and 4.4 below.

4.3 Electrical Testing Using IEEE 488 Communications
The SBC488 can be tested using either the supplied SBCwin program (only compatible with IOtech's IEEE 488 cards and drivers) or any IEEE 488 test facility such as IOtech's windows based QuickTest program.

4.3.1 Equipment Required
      a. IBM PC or compatible.
      b. IEEE 488 adapter card and software.
      c. Oscilloscope (optional).
      d. Fluke 77 DVM or equal.
      e. IEEE 488 cable.

4.3.2 Procedure for using the SBCwin program with IEEE 488 communications
      a. Set the address dip switch on the SBC488 to the IEEE 488 address desired. See Section 2.7 for the address switch configuration.

      b. Connect AD0 thru AD5 inputs to DA0 thru DA2 outputs to loop back analog signals if these options are installed (See figures 7 and 8).

      c. Install or verify installation of IEEE 488 card and driver software. Refer to the IOtech manual.

      d. Connect the IEEE 488 cable from the IBM PC compatible to the SBC488.

      e. Apply power to the SBC488. The SBC488's LEDs will cycle for a short time to indicate that it started properly.

      f. Turn on the IBM PC compatible and load the IEEE 488 driver (DRVR488W.EXE) and the SBCwin program.

      g. Using IOtech's CONFIG.EXE program, create a logical instrument named SBC488 with the IEEE 488 address which was

previously set on the SBC488's address dip switch. Configure
the device for CR, LF and EOI Terminators.

h. Click on the SBCwin icon to start the SBCwin program.

i. Choose the IEEE 488 interface from the interface selection
pop up window. Then enter the address that is setup on the
SBC488's dip switch in the address pop up window and click OK.
The main screen will appear and the communications light will be
green.

j. Push the DAC button for each of the installed DAC's and enter
a value from 0 to 4095. Check the readback on each ADC channel
against the DAC setting. Measure the DAC output and compare it
against the calculated value using the formulas in Section 2.

k. Individually ground (P9 pin 34) each pin corresponding to
each optional digital I/O port (See Figure 9) and verify the
readback on the SBCwin screen.

l. Set and reset each bit of each installed digital I/O port
while observing the appropriate pin using a multimeter (see
figure 9).

4.3.3 Procedure for using IOtech Quicktest Program

a. Set the address dip switch on the SBC488 to the IEEE 488
address desired. See Section 2.7 for the address switch
configuration.

b. Connect AD0 thru AD5 inputs to DA0 thru DA2 outputs to loop
back analog signals if these options are installed (See figures
7 and 8).

c. Install or verify installation of IEEE 488 card and driver
software. Refer to the IOtech manual.

d. Connect the IEEE 488 cable from the IBM PC compatible to the
SBC488.

e. Apply power to the SBC488. The SBC488's LEDs will cycle for
a short time to indicate that it started properly.

f. Turn on the IBM PC compatible and load the IEEE 488 driver
(DRVR488W.EXE) and IOtech's QuickTest program.

g. Using IOtech's CONFIG.EXE program, create a logical
instrument named SBC488 with the IEEE 488 address which was
previously set on the SBC488's address dip switch. Configure
the device for CR, LF and EOI Terminators.

h. Type the command "*IDN?" in the output data window and then
click on the Send button. Note: type the text inside the
quotation marks.

i. Click on the Read button and observe the data returned. The
data should read *SBC488,REVxx* where xx is the revision of the
firmware.

j. If DAC0 is installed, enter the command "DA0,4095" and click the
send button.

k. Read the voltage on DAC Port 0, (P3 pin 1) with respect to ground
(P3-9) with the DVM. The voltage should read full scale, i.e.
DAC_VREF*4095/4096.

l. If the ADC option is installed, enter the command AD?0 and click the
Send button.

m. Click the Read button and observe the data returned. The data should
read *xxxx* where the actual voltage is *xxxx**DAC_VREF/4096. *xxxx* can
range from 0 to 4095. This corresponds to 0 to ADC_VREF VDC on the ADC
converter.

n. Repeat steps j. thru m. for the other six ADC and DAC
channels using the following commands:

    "DA1,4095" and "AD?1"
    "DA2,4095" and "AD?2"
    "DA3,4095" and "AD?3"
    "DA4,4095" and "AD?4"
    "DA5,4095" and "AD?5"

    Note: Use only on channels with the optional DAC's
    installed.

Follow steps p-w below only for installed digital I/O ports.

o. Enter the command "D0,128" and click the Send button.

p. Read the voltages on I/O Port 0, P9 pins 2 thru 9 with
respect to P9-34 (Gnd). The voltages should read as follows.

Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2
3-5 VDC	0	0	0	0	0	0	0

q. Enter the command "D?" and click the Send button.

r. The SBC488 will respond with www,xxx,yyy,zzz where these are
the decimal representations (0-255) of each 8 bit port value.

s. Enter the command "D0,64" and click the Send button.

t. Read the voltages on I/O Port 0, P9 pins 2 thru 9 with
respect to P9-10 (Gnd). The voltages should read as follows.

Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2
0	3-5 VDC	0	0	0	0	0	0

    w. Repeat steps o. thru t. for Port 1 "D1,xxx" thru Port 3
    "D3,xxx".

4.4 Electrical Testing Using RS-232 Communications

The SBC488 can be bench tested using either the supplied SBCwin
program or any Terminal program such as the one included with
Microsoft Windows (tm).

4.4.1 Equipment Required
    a. IBM PC or compatible with Serial port.
    b. Oscilloscope (optional).
    c. Fluke 77 DVM or equal.
    d. RS-232 Cable 9 pin (SBC488 side) to computer serial port.

4.4.2 Procedure for using SBCwin program with RS-232 communications
    a. Set the address dip switch on the SBC488 to 31. See Section
    2.7 for the address switch configuration.

    b. Connect AD0 thru AD5 inputs to DA0 thru DA2 outputs to loop
    back analog signals if these options are installed (See figures
    7 and 8).

    c. Install or verify installation of serial card and driver
    software.

    d. Connect the RS-232 cable from the IBM PC compatible to the
    SBC488.

    e. Apply power to the SBC488. The SBC488's LEDs will cycle for
    a short time to indicate that it started properly.

    f. Turn on the IBM PC compatible and load the SBCwin program.

    h. Click on the SBCwin icon to start the SBCwin program.

    i. Choose the RS-232 interface from the interface selection pop
    up window. Then enter the port that the SBC488 is connected to
    in the address pop up window and click OK. The main screen will
    appear and the communications light will be green.

    j. Push the DAC button for each of the installed DAC's and enter
    a value from 0 to 4095. Check the readback on each ADC channel
    against the DAC setting. Measure the DAC output and compare it
    against the calculated value using the formulas in Section 2.

    k. Individually ground (P9 pin 34) each pin corresponding to
    each optional digital I/O port (See Figure 9) and verify the
    readback on the SBCwin screen.

    l. Set and reset each bit of each installed digital I/O port
    while observing the appropriate pin using a multimeter (see
    figure 9).

4.4.3 Procedure for using the Terminal Program

    a.   Set the SBC488 address dip switch to 31. See Section 2.7 for the address switch configuration.

    b.   Connect AD0 thru AD5 inputs to DA0 thru DA2 outputs to loop back analog signals if these options are installed (See figures 7 and 8).

    c.   Install or check installation of serial card.

    d.   Connect the RS-232 cable to the SBC488.

    e. Apply power to the SBC488. The SBC488's LEDs will cycle for a short time to indicate that it started properly.

    f.   Turn on the IBM compatible PC.

    g.   Run the terminal setup program and configure the port to 9600 baud, no Parity, 8 bit data and 1 stop bit.

    h.   Type the command "*IDN?" in the terminal area and then press return.

    i.   The SBC488 should return *SBC488,REVxx* where xx is the revision of the firmware.

    j.   If the DAC0 option is installed, enter the command "DA0,4095" and press return.

    k.   Read the voltage on DAC Port 0, P3 pin 1 with respect to P3-34 with the DVM. The voltage should read full scale.

    l. If the ADC option is installed, enter the command "AD?0" and press return.

    m.   The SBC488 should return *xxxx* where the output voltage is *xxxx**FS_ADC/4096. *xxxx* can range from 0 to 4095 corresponding to 0 to full scale on the ADC.

    n.   Repeat steps i. thru m. for the other five optional ADC and DAC channels using the commands:

        "DA1,4095" and "AD?1"
        "DA2,4095" and "AD?2"
        "DA3,4095" and "AD?3"
        "DA4,4095" and "AD?4"
        "DA5,4095" and "AD?5"

    o.   If the Digital I/O option is installed, enter the command "D0,128" and press return.

Follow steps p-w below only for installed digital I/O ports.

p. Read the voltages on I/O Port 0, P9 pins 2 thru 9 with
respect to P9-34 (Gnd). The voltages should read as follows.

Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2
3-5 VDC	0	0	0	0	0	0	0

q. Enter the command "D?" and press return.

r. The SBC488 will respond with www,xxx,yyy,zzz where these are
the decimal representations (0-255) of each 8 bit port value.

s. Enter the command "D0,64" and press return.

t. Read the voltages on I/O Port 0, P9 pins 2 thru 9 with
respect to P9-10 (Gnd). The voltages should read as follows.

Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2
0	3-5 VDC	0	0	0	0	0	0

w. Repeat steps o. thru t. for Port 1 "D1,xxx" thru Port 3
"D3,xxx".

5.0 Programming

5.1 Device Specific Commands

The SBC488 is addressable via the IEEE 488 interface and the RS-232 interface. The SBC488 assumes IEEE 488 communications if the address switch is set in the range of 0 to 30 (valid IEEE 488 address) and RS-232 communication for a setting of 31. The device specific commands are implemented for both interfaces. The IEEE 488 commands listed in Section 5.2 are only available over the IEEE 488 interface (with the exception of *IDN?). Example programs use IOtech's DRIVER488/DRV driver syntax but should be helpful as a guide for other drivers.

The following are the device specific commands:

a.   Set Digital to Analog Converter (DAC)

   DAy,xxxx where xxxx is desired output voltage multiplied by
   FS_Volts*xxxx/4096. xxxx can range from 0 to 4095 corresponding
   to 0 to DAC_VREF VDC*4095/4096 on the DAC. y is the DAC channel
   and is valid from 0 to 5, assuming that 5 DAC's are installed
   Response: None

   QuickBasic Example using DAC set commands

```
        'QuickBasic Example using DAC set commands
        OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
        OPEN "\DEV\IEEEIN" FOR OUTPUT AS #2
        'ASSUME SBC488 IS AT ADDRESS 9
        'ASSUME DAC VREF AND ADC VREF ARE BOTH 2.5 VDC
        FS_VOLTS=16              'FULL SCALE VOLTAGE IS 16 VDC
        FS_AMPS=320             'FULL SCALE CURRENT IS 320 ADC
        V_SET=5.5                  'VOLTAGE SETTING IS 5.5 VDC
        I_SET=100                  'CURRENT SETTING IS 100 AMPS
        OV_SET=6.5                 'SET OVERVOLTAGE TO 6.5 VOLTS
        PRINT#1, "OUTPUT9;DA0,"+RIGHT$(STR$(V_SET*8192/(2.5*FS_VOLTS)),4)
        PRINT#1, "OUTPUT9;DA1,"+RIGHT$(STR$(I_SET*8192/(2.5*FS_AMPS)),4)
        PRINT#1, "OUTPUT9;DA2,"+RIGHT$(STR$(OV_SET*8192/(2.5*FS_VOLTS)),4)
```

b.   Read Analog to Digital Converter (ADC)
   AD?y
   Response: returns xxxx. Actual output voltage is
   xxxx*FS_Volts/4096. xxxx can range from 0 to 4095 corresponding
   to 0 to F.S. on ADC. y can be 0 to 10. This assumes that the
   ADC option is installed.

c. Read Digital Input/Output (I/O)

   D?
   Response: returns www,xxx,yyy,zzz where these are the decimal
   representations (0-255) of each 8 bit port.

d. Write Digital I/O

Dy,xxx where xxx is a decimal number representing the binary weighted value of the port and y is the port number. y is valid only from 0 to 3 and only when the corresponding optional port is installed.

Response: None

QuickBasic program using Digital I/O

```
'QuickBasic Example using digital I/O

OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
OPEN "\DEV\IEEEIN" FOR OUTPUT AS #2
'ASSUME SBC488 IS AT ADDRESS 9
'D?1 COMMAND POSITIONS
START=1
STOP=2
REM_SHUTDOWN=4
OV_RESET=8
'D?0 COMMAND BIT POSITIONS
C_MODE=1                        'current mode
V_MODE=2                        'volt mode
SS_MODE=4                       'soft-start mode
OT=8                            'thermal fault
PH_BAL=16                       'phase balance fault
PGM_LINE=32                     ' program line fault = 32
OV=64                           ' over-voltage fault
STDBY=128                       ' standby mode

PRINT#1, "OUTPUT9;D1,"+STR$(START)    'HIT START
PRINT#1, "OUTPUT9;D1,0"               'RELEASE START
PRINT#1, "OUTPUT9;D1,"+STR$(STOP)     'HIT START
PRINT#1, "OUTPUT9;D1,0"               'RELEASE STOP
PRINT#1, "OUTPUT9,D?,0"
INPUT #2, R$
IF VAL(R$) AND C_MODE THEN PRINT "CURRENT MODE"
IF VAL(R$) AND V_MODE THEN PRINT "VOLTAGE MODE"
IF VAL(R$) AND SS_MODE THEN PRINT "SOFT START MODE MODE"
IF VAL(R$) AND OT THEN PRINT "OVER TEMPERATURE FAULT"
IF VAL(R$) AND PH_BAL THEN PRINT "PHASE BALANCE FAULT"
IF VAL(R$) AND PGM_LINE THEN PRINT "PROGRAM LINE FAULT"
IF VAL(R$) AND OV THEN PRINT "OVER VOLTAGE FAULT"
IF VAL(R$) AND STDBY THEN PRINT "STANDBY MODE"
```

5.2 IEEE 488 Event Processing

All of the device specific commands in the previous section are initiated by the IEEE 488 bus controller. The SBC488 however, like all IEEE 488 compatible device, can also initiate activity by generating a service request. This is done by activating the SRQ line. To accommodate this feature, the bus controller must be programmed to handle service request, usually in an interrupt handling sub-routine.

The IEEE 488 standard defines a method for status reporting. This method uses the IEEE 488.1 status byte (See Figure 13). Three bits of this byte are defined as follows:

    RQS =>Service Request bit
    ESB =>Event Status bit

     MAV =>Message Available bit

The RQS bit is set when the SBC488 has requested service via the SRQ
control line.

The Event Status Bit (ESB) is set when one of the events defined in
the standard Event Status Register (ESR) has occurred. The ESR is
masked by the Event Status Enable register (ESE) so that the user can
mask specific or all events from causing an ESB and subsequent SRQ.
(See Figures 12 and 13)

The Message AVailable bit (MAV) is set when a message is available in
the SBC488 output buffer.
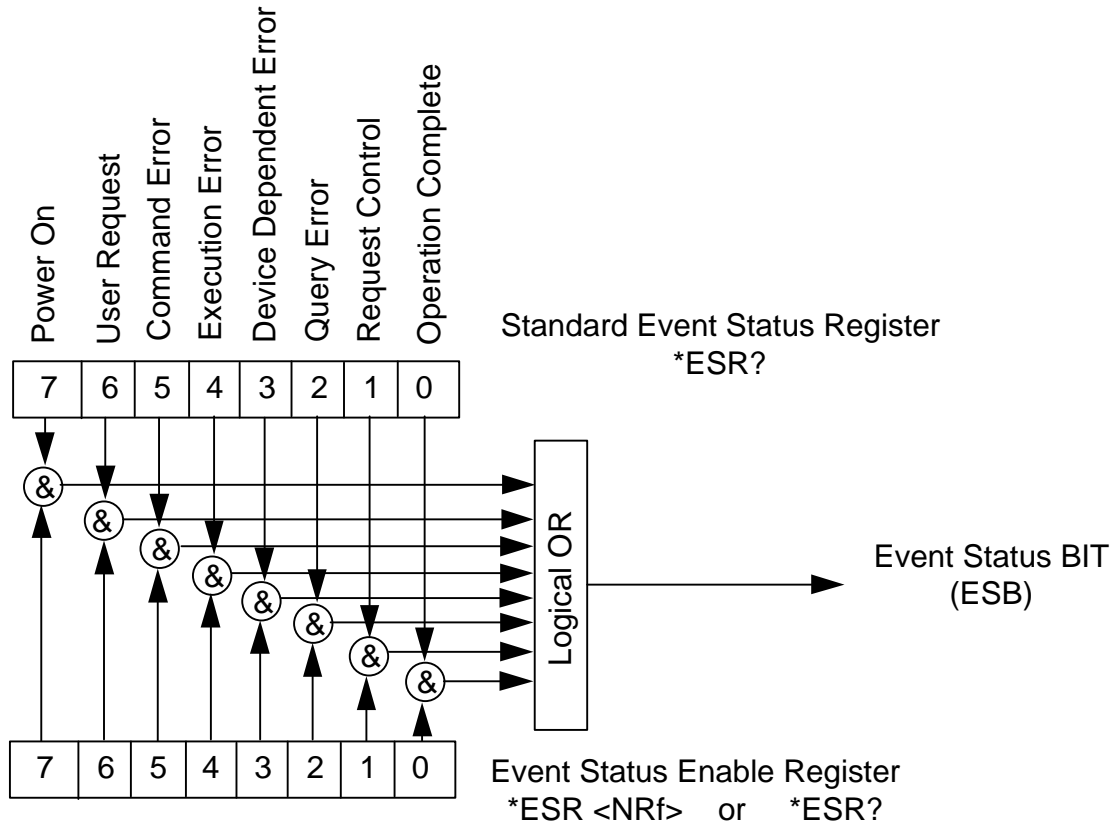
Figure 12, ESE and ESR Generation
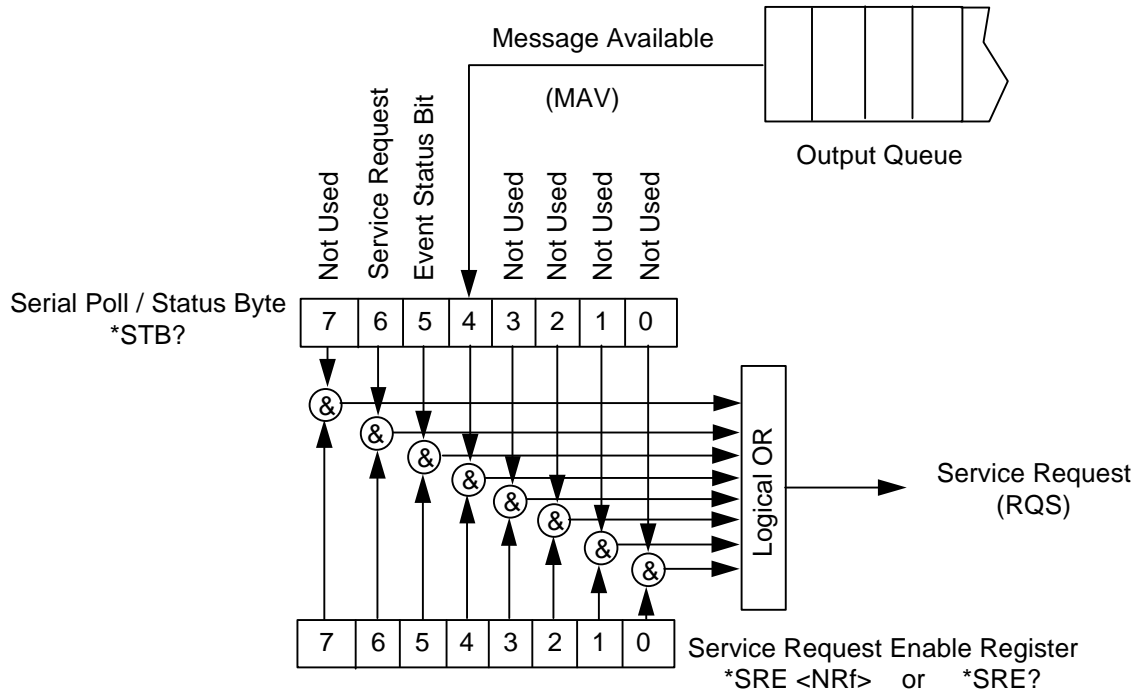
Figure 13, Status Byte Generation

5.3 IEEE 488 Standard Commands

a. Read Event Status Register (See Figure 12)

>   ***ESR?**
>   Response: Decimal number weighted as follows:
>
>   1 => Operation Complete
>   2 => not used (Request Control)
>   4 => not used (Query Error)
>   8 => Device Dependent Error
>   16 => Execution Error
>   32 => Command Error
>   64 => not used (User Request)
>   128 => Power on, 1 after power on
>
>   Note:
>   1. Power on bit is set every time the SBC488 is reset.
>   It can be used to detect a power outage or SBC488
>   reset..
>   2. All bits are cleared after the *ESR? command is
>   executed.

b. Read Event Status Enable mask (See Figure 12)

>   ***ESE?**
>   Response: Reads the *ESE mask. The mask is bitwise anded with
>   ESR and enables ESR generation. This command uses the same
>   format as *ESR? above.

c. Set Event Status Enable mask (See Figure 12)

    *ESE,xxx
    Response: Sets the *ESE mask. Mask bitwise enables ESR
    generation. Same format as *ESR? above.

d. Read Status byte (See Figure 12)

    *STB?
    Response: Decimal number weighted as follows:

        1 => N/A
        2 => N/A
        4 => N/A
        8 => N/A
        16 => MAV, Message Available
        32 => ESB, Event Status Bit
        64 => RQS, Request Service
        128 => N/A

e. Read Status Register Enable mask (See Figure 12)

    *SRE?
    Response: xxx Mask bitwise enables ESR generation. Decimal
    number weighted as follows

        1 => N/A
        2 => N/A
        4 => N/A
        8 => N/A
        16 => MAV, Message Available
        32 => ESB, Event Status Bit
        64 => N/A
        128 => N/A

f. Set Status Register Enable mask (See Figure 12)

    *SRE,xxx
    The same as format as *SRE? above.

g. Read SBC Part and serial number

    *IDN?
    Response: SBC488,REVxx where xx is the revision of the firmware.

5.4 Program Example using IEEE 488 Standard Commands

QuickBasic Program Example using IEEE 488 Standard Commands

```
'QuickBasic Example using digital I/O

OPEN "\DEV\IEEEOUT" FOR OUTPUT AS #1
OPEN "\DEV\IEEEIN" FOR OUTPUT AS #2
'ASSUME SBC488 IS AT ADDRESS 9
'SRE BIT POSITIONS
MAV=16                  'MAV, Message Available
ESB=32                  'ESB, Event Status Bit
'ESE BIT POSITIONS
DDE=8                   'Device Dependent Error
EE=16                   'Execution Error
COMERR=32               ' Command Error
PON=128                 ' Power on              , 1 after power on

'GET SBC488 VERSION NUMBER
PRINT#1, "OUTPUT9,*IDN?"
INPUT #2, R$
PRINT "FIRMWARE VERSION NUMBER "+R$

'ENABLE  MAV AND ESB IN SRE AND READ BACK
PRINT#1, "OUTPUT9,*SRE,"+STR$(MAV+ESB)
PRINT#1, "OUTPUT9,*SRE?"
INPUT #2, R$
PRINT "SERVICE REQUEST ENABLE REGISTER IS SET TO"+R$

'ENABLE PON AND COMERR IN SRE AND READ BACK
'POWER ON AND COMMAND ERRORS WILL PRODUCE SERVICE REQUESTS
PRINT#1, "OUTPUT9,*ESE,"+STR$(PON+COMER)
PRINT#1, "OUTPUT9,*ESE?"
INPUT #2, R$
PRINT "EVENT STATUS ENABLE REGISTER IS SET TO"+R$
```

6.0 TROUBLESHOOTING

FAULT CONDITION	PROBABLE CAUSE	CHECK, REMEDY
No IEEE 488 Communications	Address errors Note 3	SBC488 Dip switch. Valid addresses are 0 thru 30 Control program address
	Termination	Check control program termination, CR, LF and EOI
	IEEE 488 Cable	Replace Cable
	SBC488 Power Supplies	Check power supplies on SBC488 (U7).
	SmartCore Failure	Check data bus for activity

No IEEE 488 Communications (Continued)	7210 Chip failure	Check Interrupt line out of 7210 during transmission.
No RS-232 Communications	Address errors Note 3	SBC488 Dip switch. Valid address is 31.
	Format error	Terminal program set for 9600,N,8,1
	RS-232 Cable	Replace Cable
	SBC488 Power Supplies	Check power supplies on SBC488 (U7).
	SmartCore Failure	Check data bus for activity
	RS-232 transceiver Chip failure	Check U85 RX and TX lines during transmission
DAC out voltage error	DAC power supply	Check DAC power supply voltage (U1 and U2)
	Opto-Isolator failure	Check U41 and U42 outputs while commanding voltage change.
	Voltage reference	Check U21 for 2.50 VDC
	DAC IC failure	Replace U11
	Control software	Check data for errors
ADC Readback error note 1	ADC power supply	Check ADC power supply voltage (U5 and U3)
	Opto-Isolator failure	Check U43, U46 and U45 outputs while reading voltage over bus (AD?0).
	Voltage reference	Check U22 for 2.50 VDC
	ADC IC failure.	Replace U90
	Control software	Check data for errors
Digital Readback error	Digital power supply	Check power supply voltage (U6)
	Opto-Isolator failure	Check U48 and U47 outputs while reading digital over bus (D?0).
	Control software	Check data for errors
	Port IC failure	Replace port IC U51, U52 or U53
	Voltage levels	Verify input voltage levels are valid (See section 2)
Digital set error	Digital power supply	Check power supply voltage (U6)
	Opto-Isolator failure	Check U48 and U47 outputs while reading digital over bus (D?0).
Digital set error (Cont'd)	Control software	Check data for errors
	Port IC failure	Replace port IC U51, U52 or U53
	load current note 2	Verify load current levels are valid (See

section 2)

Notes:

1. ADC input voltages outside of specified input range may cause the
IC to latch and fail.

2. Digital output ports may require a pull up resistor for certain
loads to increase the source current available. RN21 thru RN24 are
optional pull-up resistors that are socketed for easy installation.

3. Always cycle SBC488 power after changing dip switch setting.

7.0 DRAWINGS

7.1 SBC488 Parts List

The SBC488 Parts List is on following page.

7.2 Drawings

The SBC488 overall schematic, Figure 14 follows.
The SBC488 component layout is on Figure 15.

P/N 104101B								
ITEM	REV	QTY	REF DES	VALUE	VOLT	MPE P/N	DESCRIPTION	MFG PART NUMBER	MANUFACTURER
1		1	BT1	CR2032	3V		LITHIUM BATTERY, 20 MM	CR2032	PANASONIC
2		1	C1	100	35V			ECE-A1VSF101 (P1231	PANASONIC
3	B	25	C11,C13-C33,C38-C40	0.1	50V	11146			
4		3	C41-C43	330	16V			ECE-A1CFS331 (P1213	PANASONIC
5		1	C51	0.1	1000V	11201		ECQ-E2A104MW	PANASONIC
6		2	C52-C53	0.01	1000V			ECQ-U2A103MW	PANASONIC
7		1	C61	47	25V	12216			
8		1	C81	33	250V			ECE-A2EU330	PANASONIC
9		1	C91	220 pf	1000V	10843			
10		2	CN1-CN2	0.1	50V		CAPACITOR NETWORK, 8 PIN SIP	201CH7X7R104K5	DALE
11		1	D1	1N5230B	4.7V	10990			
12		1	D21	1N4148		10978			
13		2	D41-D42	1N5819		11291			
14		1	D61	HER102		11125			
15	B	6	DB1-DB6	DF06M		11144			
16		1	L1	25 mH		104502	COMMON MODE CHOKE		MAGNAPOWER
17		1	L2	27U				5800-270	J.W. MILLER
18		5	LED0-LED4	L20321			LED, RED, RT ANGLE	5600F1	INDUSTRIAL DEVICES INC
19		1	P1	553811-1			CONNECTOR, 24 PIN, IEEE 488		AMP
20		1	P13	929834-01			CONNECTOR, HEADER, 10 POS, SIL		3M
21		1	P14	929836		11229	CONNECTOR, 10 PIN HEADER, DIL		3 M
22		2	P22/P23	929836		11229	CONNECTOR, 34 PIN HEADER, DIL		3 M
23		1	P3	929836		11229	CONNECTOR, 24 PIN HEADER, DIL		3 M
24		1	P4	P09S-21	P09S-21		CONNECTOR, 9 PIN D-SUB, RT ANGLE	DK: 309F-ND OR A158	NORCOMP OR AMP (DUAL)
25		1	P6	26-48-103			3 POSITION CONNECTOR, .156" SPACING	26-48-1035	MOLEX
26		1	P9	929836		11229			
27		1	Q2	2N2222A		11200			
28		1	R1	2.2K		10040			
29	B	2	R12-R13	10.0K, 1%		10356			
30		6	R14-R19	10K		10048			
31		5	R21-R25	1K		10036			
32		2	R30-R31	56K		10057			
33		2	R41-R42	680		10034			
34		1	R51	220		10028			
35		1	R71	6.8		10010			
36		1	R81	56		10033			
37		1	R91	1K	1/2W	10125			

| 38		2	R95-R96	1.2K		10037			
39		3	RN9-RN11	10K			RES NETWORK, 4R 8 PIN	CSC08A-03-103	
40		1	RN12	1K			RES NETWORK, 7R 8 PIN	CSC08A-01-102	
41	B	1	RN2	10K		11274	RES NETWORK, 9R 10 PIN		
42		4	RN21-RN24	470			RES NETWORK, 9R 10 PIN	CSC10A-01-471	
43		1	RN3	10K			RES NETWORK, 5R 6 PIN	CSC06A-01-103	
44		1	RN31	10K			RES NETWORK, 9R10 PIN	CSC10A-01-103	
45		1	RN5	470			RES NETWORK, 9R 10 PIN	CSC10A-01-471	
46		1	RN8	100			RES NETWORK, 7R 14 PIN	MDP14-03-101	
47		1	SW1	A5005-ND			DIP SWITCH, 5 POSITION, RIGHT ANGLE		
48		1	SW2	CKN-5007			DPDT SLIDE SW, RT ANGLE	1101M2S3AV2BE2	C & K COMPONENTS
49		1	T1	104501		104501	FLYBACK TRANSFORMER		MAGNAPOWER
50		1	U1	LM7815CT		11169			
51		1	U100	SC-Z1B				101-0079	Z-WORLD ENGINEERING
52		1	U101	27C256-90					MICROCHIP
53		1	U110	SE1707			8 MHZ OSC., 14 PIN	SG-51P-8.000MHZ	DIGIKEY
54		6	U11-U16	LTC1257CN8			12 BIT DAC		
55		1	U21	LM4040EIZ-X			VOLTAGE REFERENCE		NATIONAL
56		1	U22	LM4040EIZ-X			VOLTAGE REFERENCE		NATIONAL
57		1	U31	PS2501-1			OPTO ISOLATOR		NEC
58		1	U35	TL431		11109			
59		5	U41,U42,U44,U47,U48	HCPL-2531					HP
60		1	U5	LM78L05				LM78L05ACZ	NATIONAL
61		4	U51-U54	PCF8574AP				PHILLIPS	
62		1	U6	LM7805CT		10914			NATIONAL
63		1	U60	LTC485CN8					LINEAR TECHNOLOGY
64		1	U61	74HC259				MM74HC259N	NATIONAL
65		1	U71	74HC541				MM74HC541N	NATIONAL
66		1	U81	uPD7210				D7210C	NEC OR NATIONAL INST.
67		1	U82	75160				DS75160AN	NATIONAL
68		1	U83	75162				SN75162BN	TEXAS INSTRUMENTS
69		1	U85	MAX202ECP					MAXIM
70		1	U88	74HC574				MM74HC574N	NATIONAL
71		1	U90	TLC2543CN			A TO D CONVERTER, 12 BITS		TEXAS INSTRUMENTS
72		1	U91	TOP200YAI					POWER INTEGRATIONS
73		1	U99	74HC04				MM74HC04N	NATIONAL
74		1	XBT1				BATTERY SOCKET, 20 MM	106K	KEYSTONE
75		1	ZR1	V145	150V		VARISTOR, 145 VAC		PANASONIC

Figure 14, SBC488 Schematic Diagram
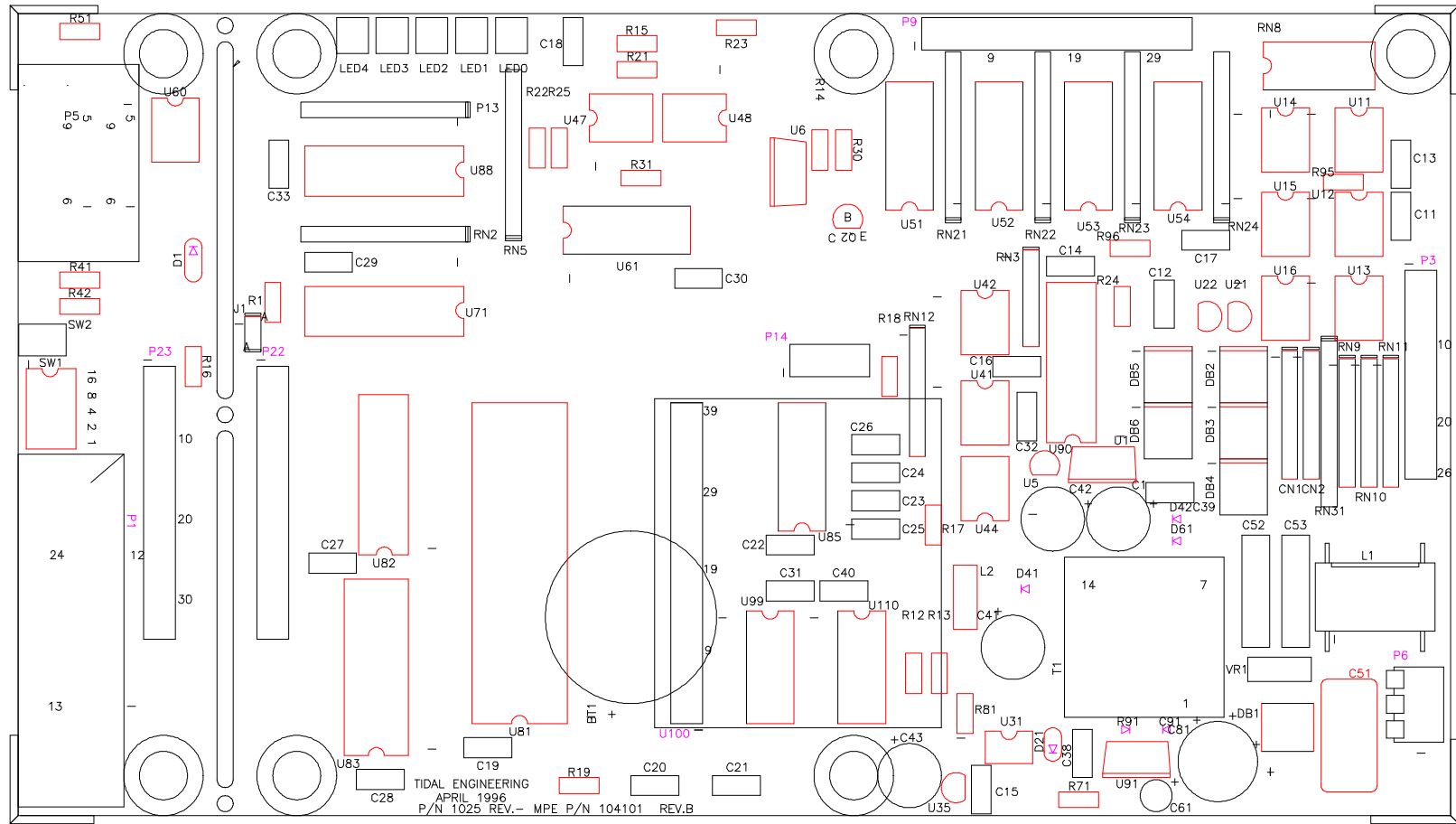
Figure 15, SBC488 Component Layout