Smart mbed

This document contains design considerations for integrating the NXP mbed into various applications using this Smart mbed board.

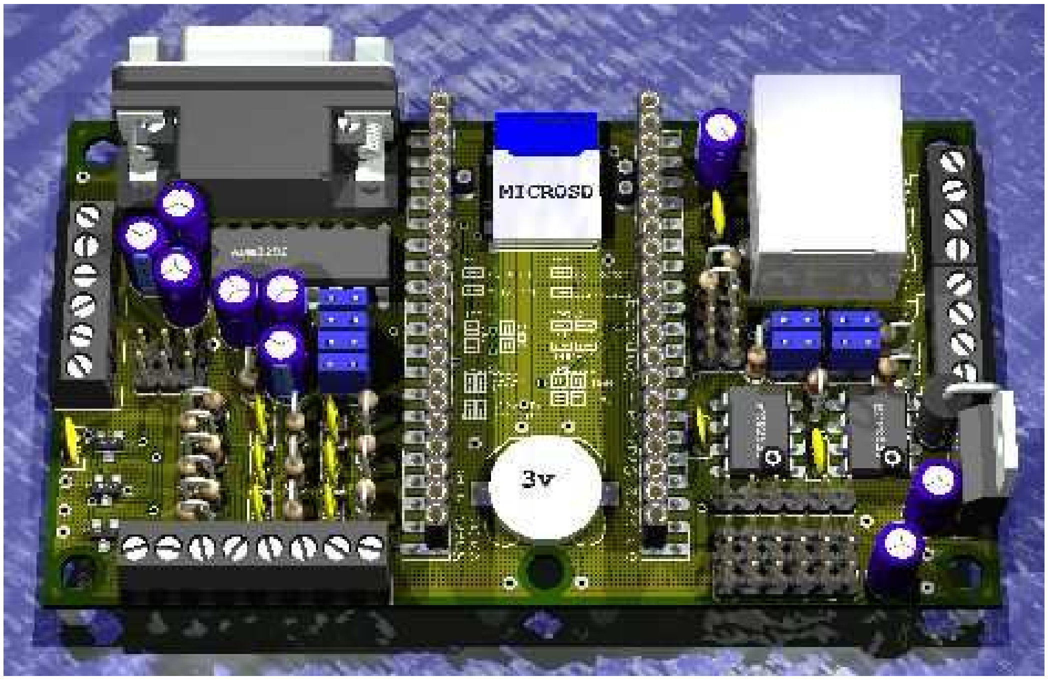

Figure 1 Smart mbed Virtual Image

Board Revision: v0.05
Document Revision: v0.05.00

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Introduction

The information in this document is intended to capture some of the considerations that went into this design. Additionally, it will present the level of optionality that is available, and give you hints where you can take it from here.

Be aware of the constraints and limitations of the mbed hardware itself. Several pins are accessible directly from the external connectors. These pins may be damaged by misapplication of voltage or current, thereby damaging the mbed. You will see some consideration has been given in the analog inputs, with protection to minimize the possibility of damage to the mbed. But there are other circuits without such protection in the design.

It should be understood that to leverage the hardware in this device, there must be corresponding software. For example, without software to leverage the Ethernet hardware, it will not communicate on Ethernet. And, without a small amount of additional software, it cannot energize the LEDs on the Ethernet connector. For the most part, the corresponding libraries on the mbed site have the needed services available to exploit the hardware capability.

External References

The mbed itself is a design by NXP. It is a proprietary hardware and software design that is intended to be leveraged for rapid prototyping and design work. All references in this document to mbed are intended to reference that product.

Links to external sites related to mbed:

- http://www.mbed.org
- http://www.nxp.com

Much of the software that can work with this hardware can be found at the mbed site.

Mechanical Interfacing

Successful integration of this board into a device involves the mechanical interface as well as the electrical and software interfaces.

In Figure 2 you can see the mechanical layout. The overall board is 4 inches wide by 2.25 inches high. There are 5 mounting locations as shown. Note that in each of the four corners, the distance inward in each direction is the same. The fifth location is in front of the battery connector, and aside from physical mounting of the PCB, it can be used to trap the battery in place so that vibration doesn't cause it to come out.

Depending on the electrical interfaces you need, you may/not require access to all four sides. This plus the bend-radius on any wires or harness and you may need an additional inch or those sides. Also, consider if you need access to the micro SD slot.

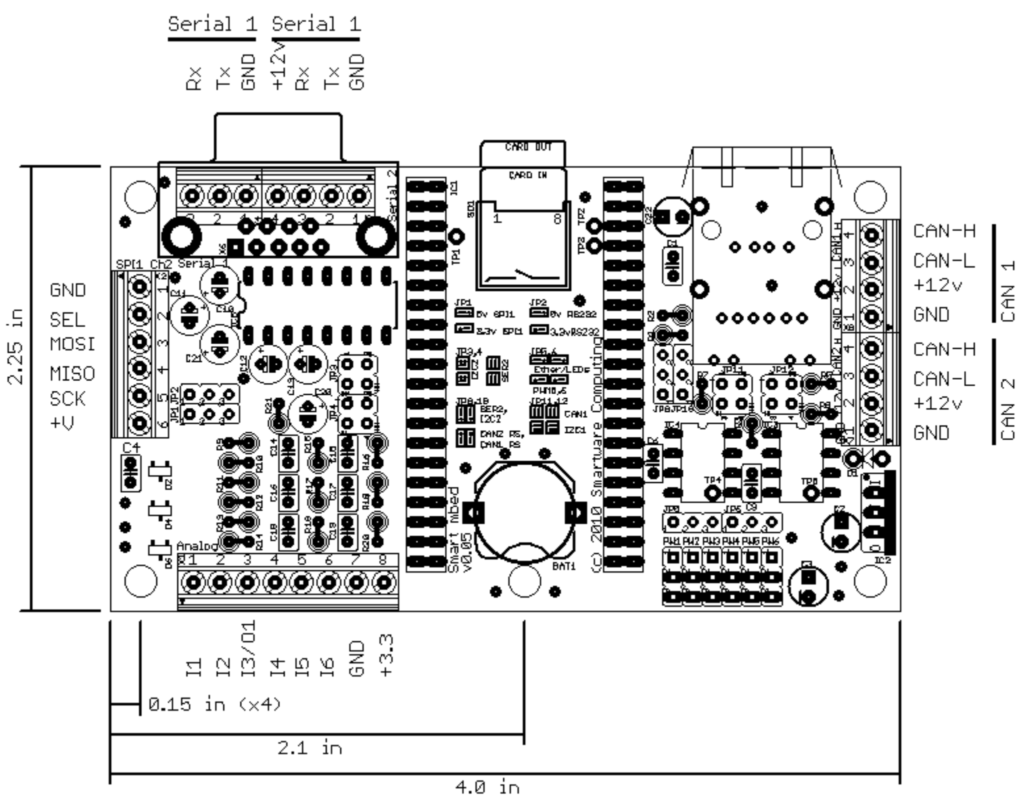

Figure 2 Mechanical and Connectors

To try to maximize the flexibility of this hardware design, there are several headers on which various configurations of jumpers will effect the electrical configuration, including what peripherals are available. To keep this information readily available, you can see it is silk-screened onto the PCB just under the mbed itself. This detail can be seen in Figure 3.

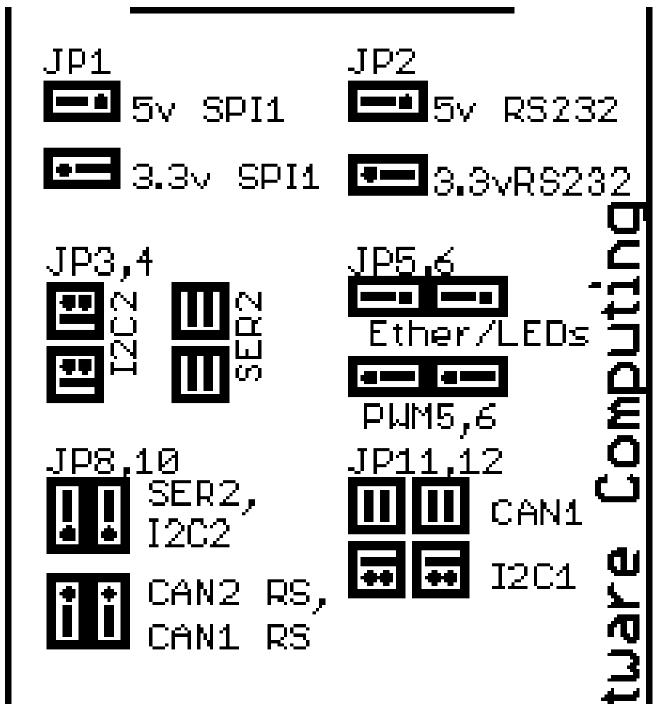

Figure 3 Jumper Configuration

Circuit Assembly

There is very little that is critical about assembling the components onto the PCB, however this section does provide a few guiding elements.

Where possible, all parts are through-hole parts for easy of assembly. There are a few exceptions.

Surface Mount Parts

You should install the surface mount parts first, because other components may get in the way of you and your soldering iron. The parts of interest are the micro SD card connector, and the analog input protection diodes. Note that there are diodes on both sides of the PCB in the same area.

Alternate Parts

The flexibility of this design includes some capability for alternate parts. This small section calls out the alternates.

The serial RS-232 channel using a fairly large DB-9 connector may be left out, and instead combinations of two other connectors may be installed. This grants access to two serial ports. Of these two serial ports, one is RS-232, and the other can be RS-232 or I^2C channel 2.

Electrical Interfacing

Power Inputs

There's quite a bit to look at with respect to the power supply circuitry. Depending on your needs, there are several ways to get power to the mbed. This section goes into that detail.

USB Powered

The breakout board is capable of being configured to operate solely from the USB connector on the mbed itself. Simply plug a USB cable into your host PC and the USB-B connector on the mbed itself. For more demanding applications, you will need to provide an external power supply.

External +12v Power Source

You can provide a voltage between about 6.5 and 30 on the appropriate pins on the CAN 1 or CAN 2 connectors. You will see that Pin 2 on each is tied to the +12v line into the 3 terminal regulator. Depending on your needs, you could feed 12v into one of these and draw 12v from the other for external circuitry. The PCB design should be able to carry a few amps between these two connectors.

NOTE: If you do not need CAN, you could populate a 2-pin connector into just the Pin1 and 2 positions. This reduces the possibility of miswiring, and can lower the cost a small amount.

On-Board 5v Regulator

If you will not source power to any 5v circuitry, then you can omit this part. Note that the mbed can draw its power from this regulator, as may be typical in an automotive application.

NOTE: In some application, this part may get hot, and it may be appropriate to provide external heat-sinking.

Regulator – Low Current/Low Noise

For low power applications, a simple linear 5v regulator is sufficient. This may also be appropriate if you are reading sensitive analog signals. But do note that with a single ground on the mbed part, for analog and digital, I don't know what the noise factor will be on the analogs. Use the TL750M05CKCSE3 for an inexpensive low dropout part.

NOTE: To support even lower input voltages, you may consider bypassing D1 with a jumper, but take care that any external reverse voltage could cause catastrophic damage to the circuits.

5v Regulator – High Voltage/High Power

If your application may experience higher input voltage, or will drive external 5v loads, as in servos on the PWM channels, then a part like the Murata Power Solutions Inc, OKI-78SR-5/1.5-W36-C may be more appropriate. This is a small switching supply that drops into the same socket as the linear part, but can handle more power, and much higher voltage than the linear part may handle.

Battery Backup

Positioned under the mbed is a battery holder, which can keep the real-time clock and a bit of ram alive when everything else is powered down.

Micro SD

Under the mbed is a micro SD connector. Various applications may want/need access to a local file system. This could be for logging data, or for serving information – like a small web server might do.

Ethernet

Ethernet is supported natively in the mbed, with the standard interface made available by an external connector with integrated magnetics. This is a dual connector that also has the USB-Host interface.

LEDs

The chosen Ethernet connector has LED indicators available in it. The design supports energizing these LEDs, if you do not need PWM channels 5 and 6.

JP5 and JP6 are used to enable the LEDs in the hardware. The appropriate software interface is required to take advantage of this hardware.

USB-Host

A USB-Host port is provided, integral to the Ethernet connector. This more expensive connector allows the PCB to be a bit smaller, thereby saving a little on the cost of the PCB, and also enabling a smaller overall package size.

USB-Peripheral

The mbed itself has a USB-Peripheral connector. This is used to install software, and can also be used as a serial communication channel to a host PC.

PWM Output

The PWM output is arranged on 3-pin headers with a pin-out that matches many common servos. Of course these outputs can also be simple on/off logic level outputs.

Analog Input

The analog input circuits are quite generic in design, and you may want or need to modify them. Figure 1 shows one channel redrawn for clarity. On the left is the screw terminal connector at the edge of the board. As you see, it is a simple resistor divider (R1, R2), with a small filter cap (C1). Depending on your needs, the optional protection diode is required (D1).

The mbed input (AIN0) is rated for an input voltage up to the value used for the reference on the A to D subsystem, which is 3.3v. What happens if it experiences a higher voltage is not well defined in the manual, but typically it begins to draw more current on the input pin and can alter the measurements on other channels as well. In extreme cases, damage may result.

Protection (D1) is recommended if it is possible for the voltage on the analog input to exceed 3.3v. Additionally keep R1 as large as possible to help limit the current.

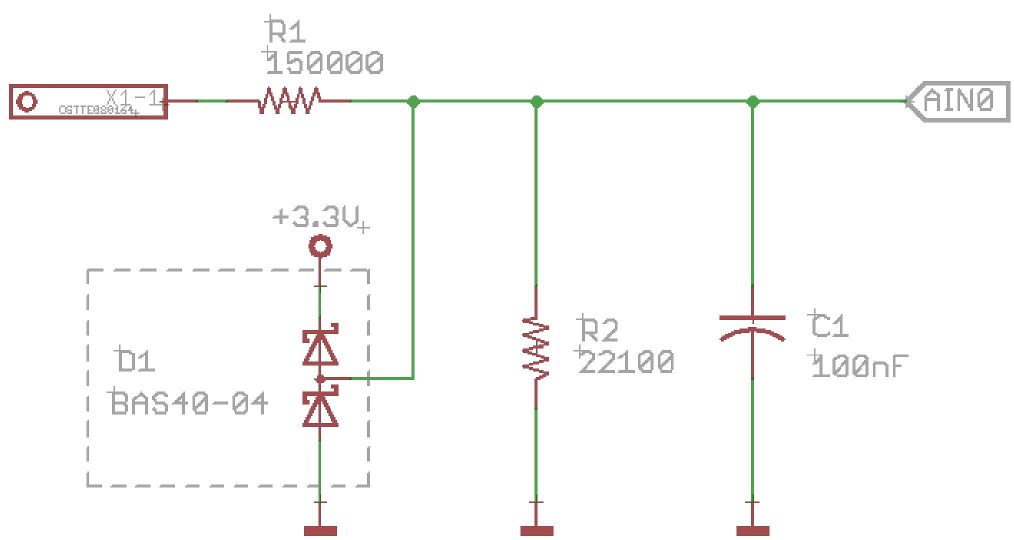

Figure 4 Analog Input

Table 1 presents a simple tool for working with the analog inputs. This is an Excel object, which you can right-click and open. Then change values in the yellow highlighted cells to the values for your designed Vin Max, R1, and R2. It will approximate the results based on the clamping diodes. Keep an eye on the power in R1, as well as on the voltage on the Analog input (V-AIN). You see a few configurations duplicated, but where either power dissipation or the input voltage was allowed to go too high – the corresponding cells turned red.

Table 1 Analog Input Calculation Tool

Vin Max (V)	R1 (Ω)	R2 (Ω)	V-AIN (V)	Current R1 (mA)	Vin mV/Bit	R1 (mW)	R2 (mW)
25.5	150000	22100	3.2745	0.148	2.809	3.3	0.0
25.5	1500	221	3.2745	14.817	2.809	329.3	0.0
3.3	10000		3.3000	0.330	3.223	0.0	
4.2	10000		3.7000	0.130	3.223	0.0	
5.0	52000	100000	3.2895	0.033	1.102	0.1	0.0
5.5	52000	100000	3.6184	0.050	1.102	0.1	0.0
V AD-Ref		3.3	Analog input reference in the mbed				
V drop (D1)		0.4	Approximate voltage drop of D1 for very low currents				

Desired Ω	Nearest 1%
101	100

There is a second tool in Table 1 that lets you determine the nearest standard 1% tolerance resistance value by entering the desired value. You can use it to “adjust” your design to commonly available parts.

Accuracy

There are many factors that can affect the accuracy of the analog input measurements. The following notes detail the most significant of these. Most of these notes refer to Figure 4.

Analog Reference – The reference voltage for the a/d converter is on the mbed. This pin is not brought out to the external connector. Instead, another 3.3v regulator is made available. The tolerance between the internal regulator and the external voltage reference may produce several bits of error – all other things being equal. For instance, if one of these is 1% high and the other is 1% low, that can attribute about 2% error – which on a 10-bit A/D could be about 20 counts!

Noise – The mbed has a single ground pin, so fluctuations in current on this carrier board and on the mbed PCB itself can induce small voltage changes. There is fairly extensive ground-plane on this carrier PCB to control the voltage drop and noise factors as best it can. But even some milli-volts represent several A/D bits.

Voltage Divider – Choose 1% resistor values or better. 1% on a 10-bit A/D is 10 counts, so you might want to look for 0.1% resistors. Expect the cost to increase with the improved tolerance.

Ratio-metric Measurement – If the external sensor is ratio-metric to an external supply voltage, then measure both. This helps cancel out the error in using a different reference. See Figure 5 for a simplified example of this type of circuit.

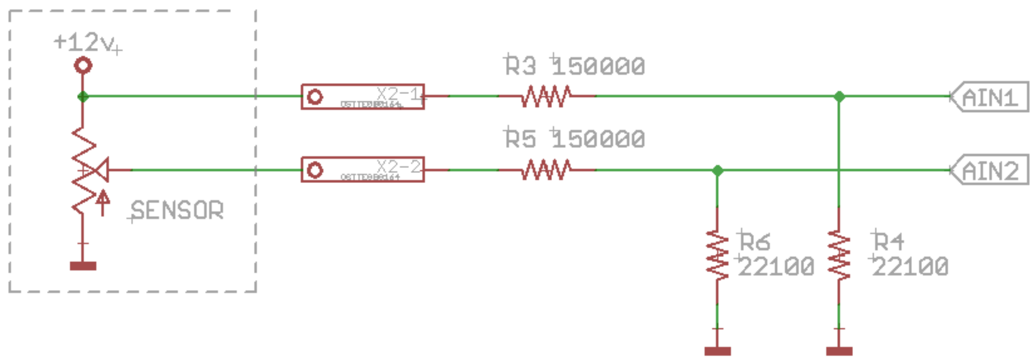

Figure 5 Ratio Metric Sensing

Frequency Response

I'll leave this next item as an exercise for the user, with a few mentions. Still referring to Figure 4, C1, in combination with R1 and R2 provide a little "smoothing" of the input voltage as presented to the A/D. The higher the value the slower the response and less "noise" will get through into the A/D (at least on this electrical path). But it also means that your software will not follow a rapid signal. This tradeoff depends on what you want to measure. If you are measuring ambient temperature, it doesn't change very fast, so a larger capacitor will likely not reduce the performance of your device. If you wanted to measure a sensor coupled to a rapidly moving wheel, then you may need a smaller value and put up with additional noise on the input.

Analog Output

Analog Input channel 3 can be reconfigured to be an analog output channel. It is likely you'll also have to reconfigure different values for the resistors and capacitors on that electrical path. For instance, you may want to implement A/C coupling of the signal by placing C1 where R1 is (see Figure 4).

Serial Channel(s) 1 and 2

There are up to 3 serial channels in this design.

RS-232 Channels

DB-9 – Single RS-232 Channel

By installing the DB-9 connector, you are limited to serial channel 1, which has simple Rx and Tx lines on the DB-9.

Headers – Dual RS-232 Channels

If you install X4 and X5 connectors, and the appropriate jumpers on JP3 and JP4, then you can have access to two RS-232 channels, or you could use two of the lines as hardware handshake for serial channel 1.

X4 – Serial Channel 1

X5 – Serial Channel 2 (or hardware handshake for Channel 1)

X8 – Serial Channel 3 (if not used for CAN Channel 1)

I^2C Channel 2

I^2C channel 2 can be enabled if you do not need the RS-232 DB-9 connector.

X5 – I^2C channel 2

Configure the appropriate jumpers in JP3 and JP4 to route these signals.

SPI Channel 1

Micro SD

The micro SD adapter, which is positioned under the mbed socket, is on SPI channel 1. Use this to either read from or write to from your applications.

SPI Channel 1 Port 2

SPI Channel 1 can also be accessed on X2. Take care in software that you may have to access this and the micro SD mutually exclusively.

Also, external hardware can be powered from this board at either 5v or 3.3v depending on the JP1 configuration.

CAN Channel(s)

This is a popular communication network on modern cars and trucks. Unlike RS-232, USB and Ethernet, CAN is multi-drop, as you see in Figure 6. Depending on the transceiver there can be 20, 30, or more nodes on one single pair of wires. It is common to use twisted pair, and it is also common to have a common ground (which is very typical of vehicle applications).

Typical data rates for CAN range from 20 kbits/sec up to 1 megabits/sec.

A CAN-based network has other attributes that make it quite reliable and quite robust. Search online for one of the many tutorials and you'll understand that value of CAN.

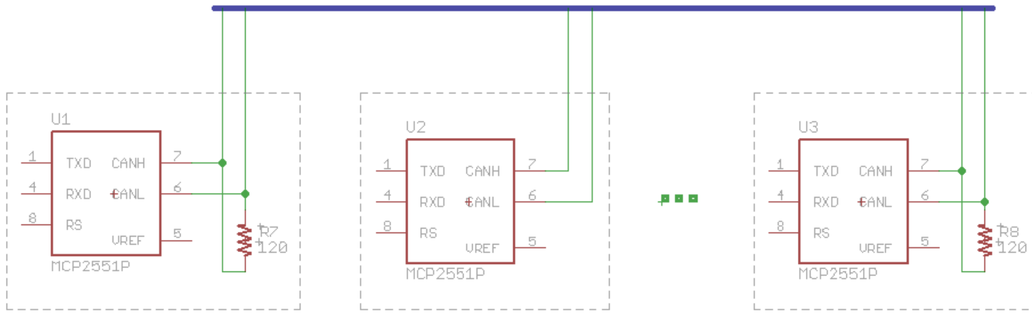

Figure 6 CAN Network

This design supports up to 2 channels of CAN communications as defined next.

Important to CAN are the terminating resistors. In Figure 6 you see one in each module at the end of the network. The module(s) in the middle should not have the termination.

While locations on the PCB support installation of termination resistors, the best-practice is to put them in the harness. In this way, you could swap one board for another and not have to add or remove the termination.

CAN Channel 2

CAN channel 2 is available on connector X7.

Additionally, R7 and JP8 can be used to control the behavior. With these two items and depending on the CAN chip that was designed in, you can control the wave-shape to reduce electrical interference possibilities. You can also configure the mbed to put CAN into a listen only or low power state.

CAN Channel 1

CAN channel 1 is available on connector X8.

CAN channel 1 is described second, because it can by bypassed and the connector pins can be I^2C channel 1 or Serial channel 3. For these two latter choices, it is likely you will need external signal conditioning as these pins are direct and unprotected from the mbed. If you are communicating directly to another board, you may not need the signal conditioning.