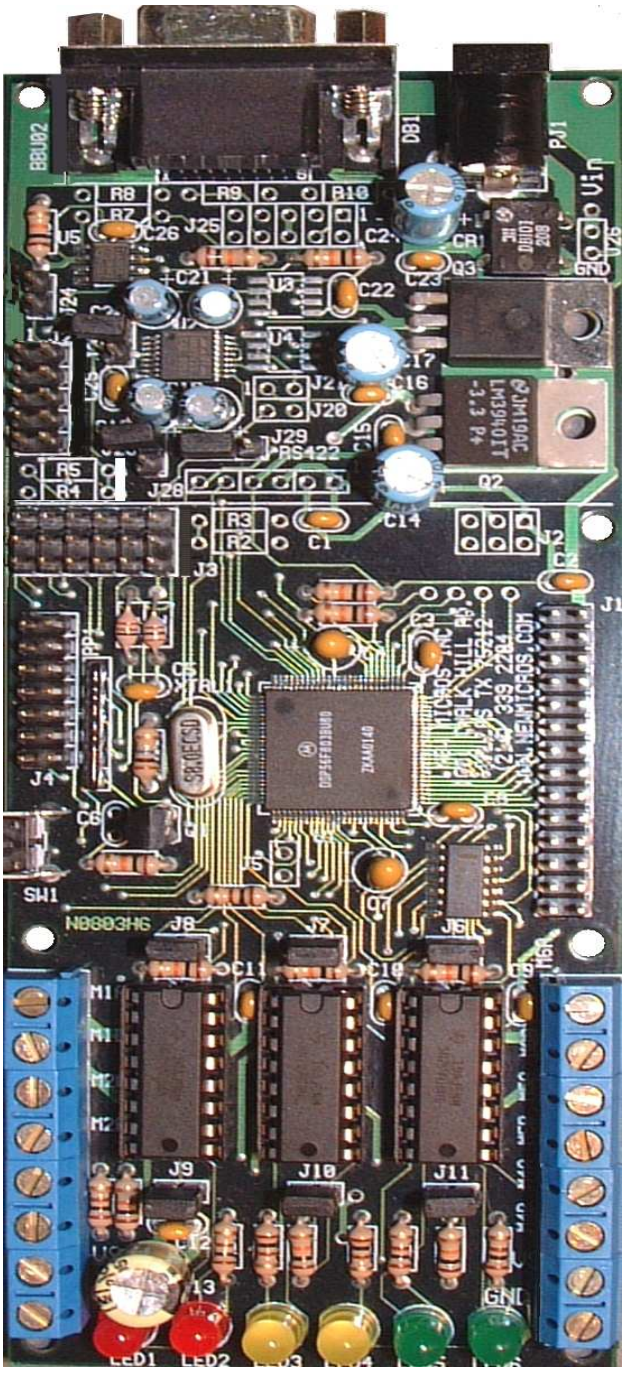
NMIN-0803-H6
User Manual

DSP65F803 Controller Board
with Three 1A Quadruple Half-H Driver



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Internet Access

Web site: http://www.newmicros.com

This manual: http://www.newmicros.com/store/product_manual/NMIN-0803-H6.pdf

Email technical questions: techsupport@newmicros.com

Email sales questions: nmisales@newmicros.com

Also see “Manufacturer” information near the end of this manual.

Internet NMIN-0803-H6 Discussion List

We maintain the NMIN-0803-H6 discussion list on our web site. Members can have all questions and answers forwarded to them. It’s a way to discuss NMIN-0803-H6 issues.

To subscribe to the NMIN-0803-H6 list, visit the Discussion section of the New Micros, Inc. website.

This manual is valid with the following software and firmware versions
- (c) 2000-2001 Motorola Inc. S-Record loader.

If you have any questions about what you need to upgrade your product, please contact New Micros, Inc.

1 GETTING STARTED

Thank you for buying the NMIN-0803-H6. We hope you will find the NMIN-0803-H6 to be useful controller board we intended it to be, and easy to use as possible.

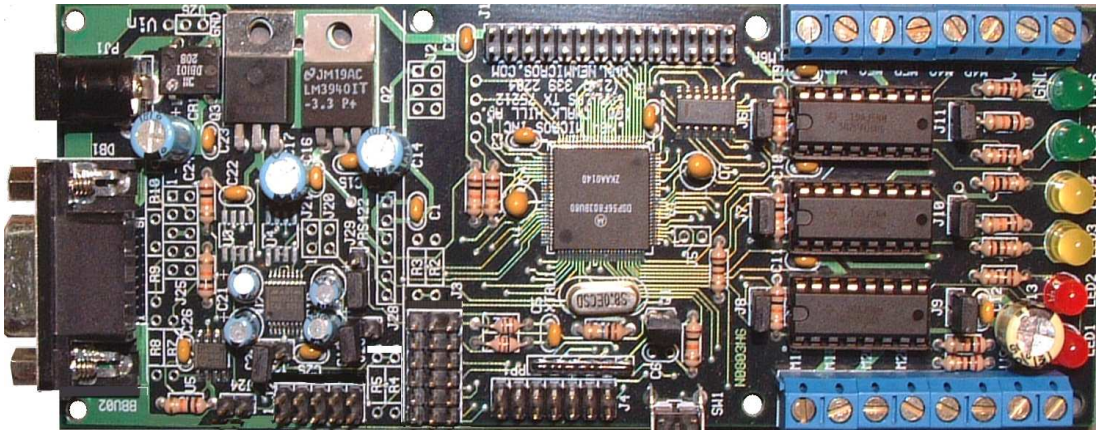

Figure 1 – NMIN-0803-H6

Let's skip the features and get right to the operation. Once we've got communications, then we can make some lights blink and know for sure that we're in business. Let's make this NMIN-0803- H6 board talk to us!

Connect a straight through serial cable DB9F to DB9M from your PC to the NMIN-0803-H6 Serial connector labels DB1. Most PC's have a DB9M connector, but may be a DB25M on older PC's. For newer PC's or laptop which does not have a serial DB9 connection, you'll need a USB to DB9M serial adapter cable.

Then you'll need the power. An AC or DC transformer from 8V to 12VDC with minimum of 300mA or higher is recommended.

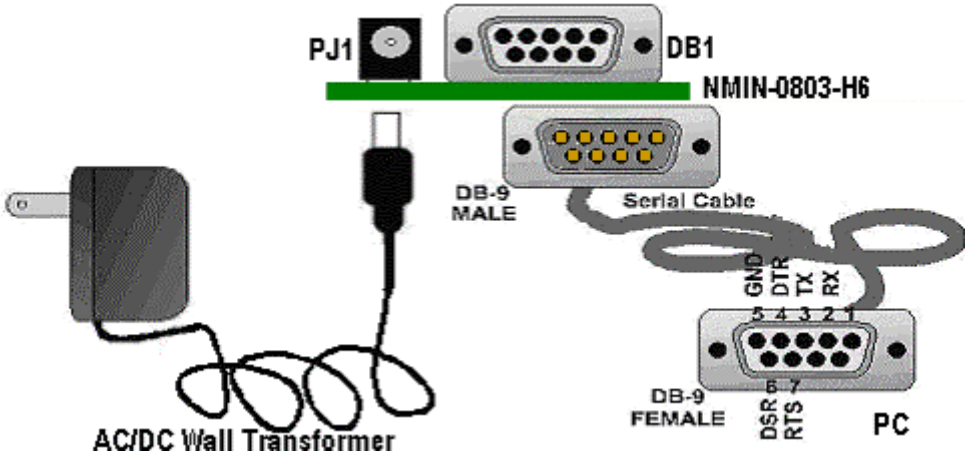

Figure 2 – Power & Serial Cable

1.1 Instructions for Serial Bootloader Users

By default, the NMIN-0803-H6 comes with the Serial Bootloader program preloaded in the program flash memory. This is the most economical way to communicate with the processor without the need of any extra hardware requires. To take advantage of the serial bootloader program, you'll need a PC running a terminal program which most PC's are come with Hyper Terminal program when purchase. Run the Hyper Terminal program, and select an available Comport. The communication parameters are set to 115,200 Baud, 8 Data Bit, None Parity, and 1 Stop bit. In the ASCII Setting option, you must set the Line delay for at least 50ms or longer to provide proper timing for S-Record downloading. See Figure 3 below for HyperTerm ASCII settings.

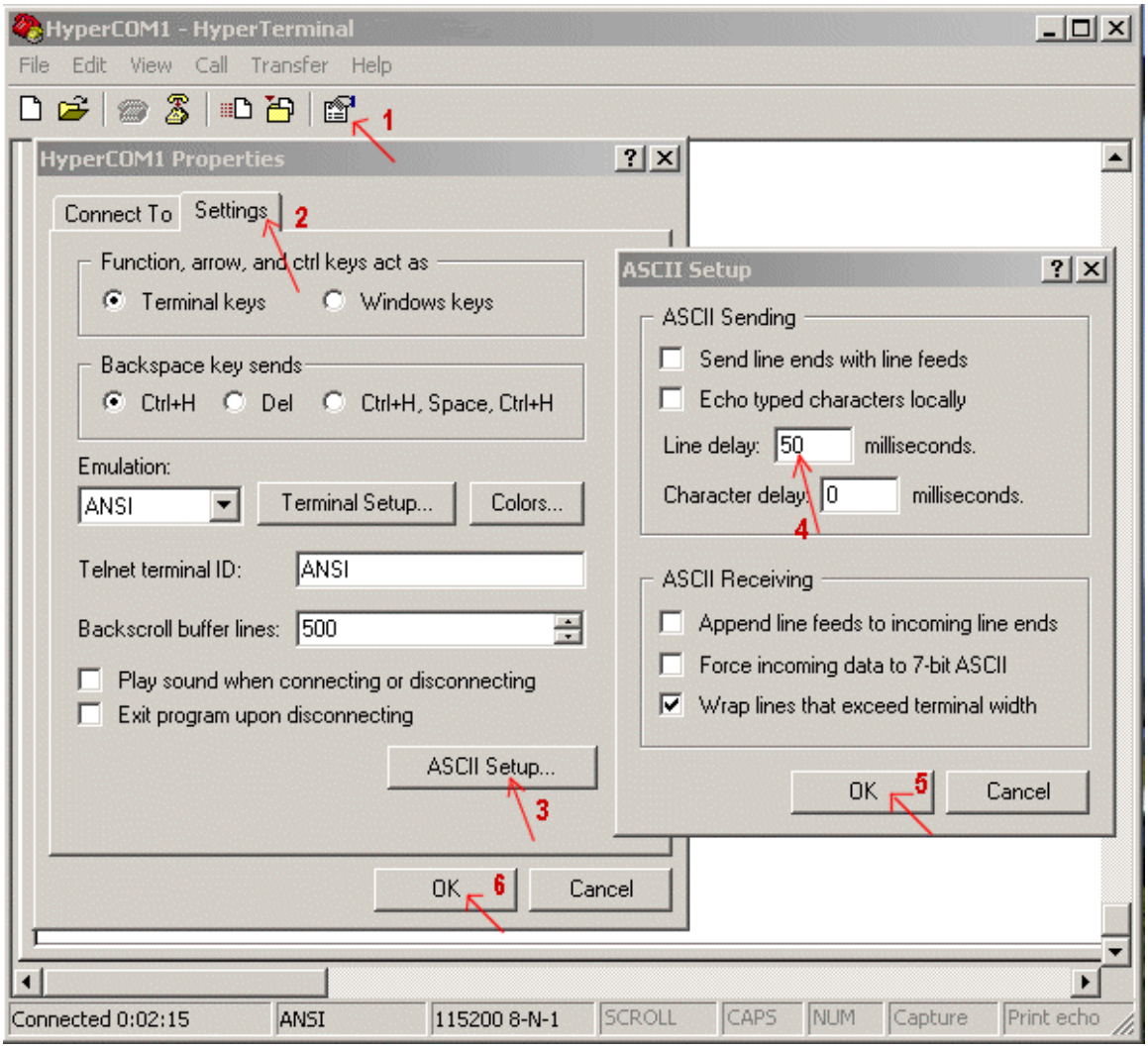

Figure 3 – Hyper Terminal ASCII Setting for Serial Bootloader

Alternately, If you do not have the Hyper Terminal program, You can download the NMITerm program provided on NMI web site,
http://www.newmicros.com/download/software/NMI/NMITerm.zip

The same as the Hyper Terminal Settings. The communication parameters are set to 115,200 Baud, 8 Data Bit, None Parity, and 1 Stop bit. Line delay must set for at least 50ms or longer. See Figure 4 for NMITerm ASCII settings.

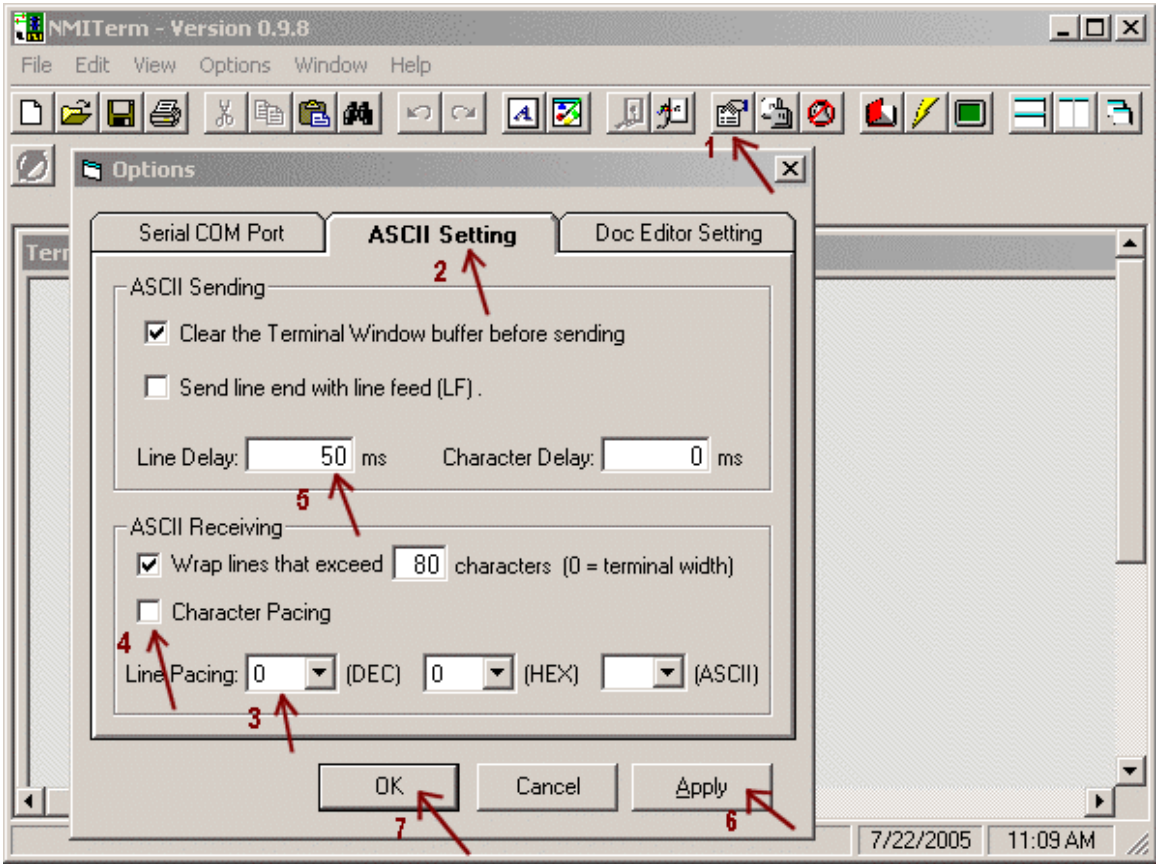

Figure 4 – NMITerm ASCII Setting for Serial Booloader

Now, while watching the LED's plug in the wall transformer connector to the power jack, PJ1 on the NMIN-0803-H6 board. All six LEDs should come on. If the LED's do not light, unplug the power to the NMIN-0803-H6 quickly, and do a quick check around to make sure the board is not placing on any conductive material, and use proper rating wall transformer or power supply.

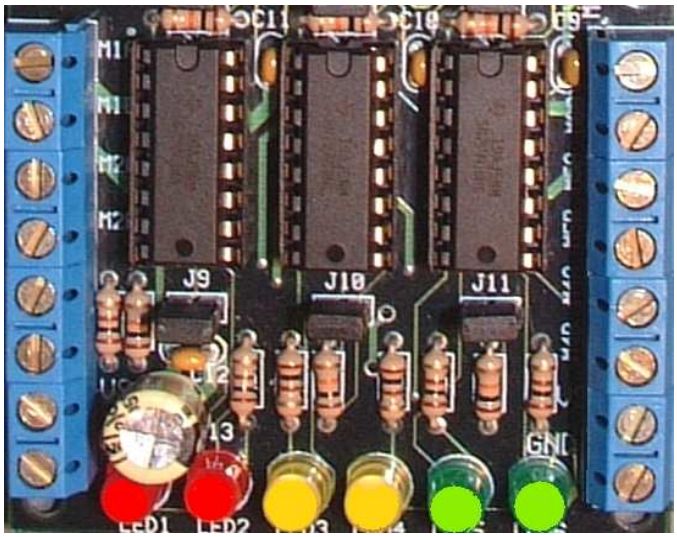

Figure 5 – H-Bridges & LEDs Section

When you connect the power to the board, all LED's are on, and a serial bootloader prompt will be displayed on the terminal program,

(c) 2000-2001 Motorola Inc. S-Record loader.

Now press any key other than "S", it will respond with,
Error # 0002
Restarting.
(c) 2000-2001 Motorola Inc. S-Record loader.

The error message is generated since the Serial Bootloader is looking for character "S" as a leading character on each line of the S-Record input file. The good news is seeing this means the NMIN-0803-H6 is communicating.

Let's download a test S-Record file from the link below,
http://www.newmicros.com/download/NMIN-0803-H6/H6leds.zip
Note: this zip file contains the **H6leds.c** (source) ,and **H6leds.s19** (S-Record). Once you have the file unzipped, you can download the Srecord file, **H6leds.s19** to the NMIN-0803-H6 flash memory and blink some LED's.

Press the reset button, SW1 to get the serial bootloader prompt
(c) 2000-2001 Motorola Inc. S-Record loader.
On the Hyperterminal window, click on **Transfer** and select **Send Text File** to download the H6leds.S19 file. It will take a few seconds to load this Srecord file, and after the file is loaded, the **H6leds** program will run and display test message on terminal.

Loaded 0x0392 Program and 0x0045 Data words.
Application started.

LED Test ready
1=LED1 ON, 2=LED2 ON,..., 6=LED6 ON. 0= ALL OFF

At this point, all LED's are turned off. It's part of the program initialization.

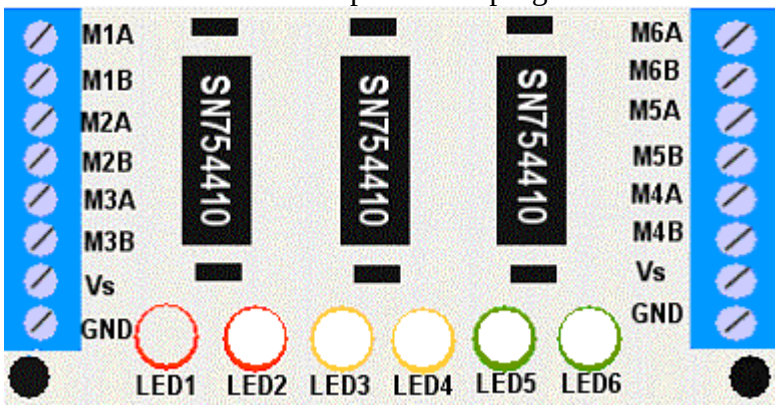

Figure 5 – LED's Initialize

To run the remaining test program, simply press a number, 1 , or 2 , …, or 6 to turn on the led(s). Or press 0 turns all off. A sample figure 6 below shows key #2, #4, and #6 are pressed.

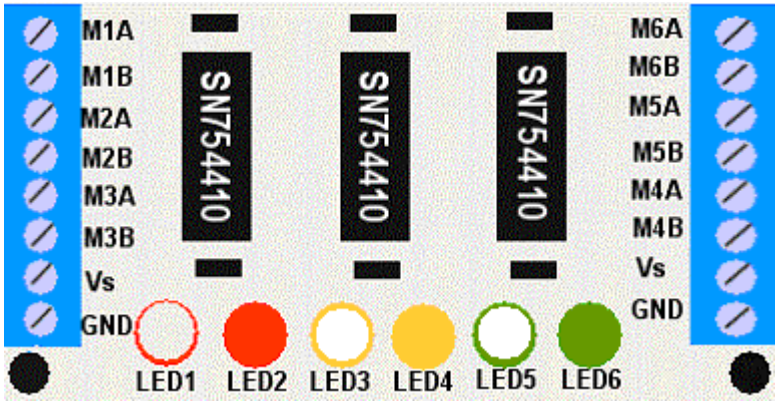

Figure 6 – LED's

To reload a new program, simply press the reset button to get the serial bootloader prompt back, ***(c) 2000-2001 Motorola Inc. S-Record loader ,*** and send your new Srecord file.

Note: After you press the reset button, there will be a 10 seconds delay period allows you to load your new Srecord file. If 10 seconds delay is expired with no Srecord file being sent, then the program previously loaded in the NMIN-0803-H6 flash memory will run. Press reset again when you are ready to load.

1.2 Instructions for IsoMax Users

IsoMax™ language can be purchased as your option, and it must load through JTAG interface. The IsoMax will be loaded at the manufacture, if you purchase the license fee at the time you order the hardware. Or you can load or upgrade firmware by yourself at anytime with the IsoMax™ Srecord file, and Jtag cable. The IsoMax license and Jtag order information are available online,
http://www.newmicros.com/cgi-bin/store/order.cgi?form=prod_detail&part=IsoMax%5BPod%5D

Once you have the IsoMax™ language loaded on your NMIN-0803-H6, you must configure the NMITerm baud rate for 115,200 and the ASCII setting as shown in figure 7 below for the IsoMax™ to communicate properly with the NMITerm program.

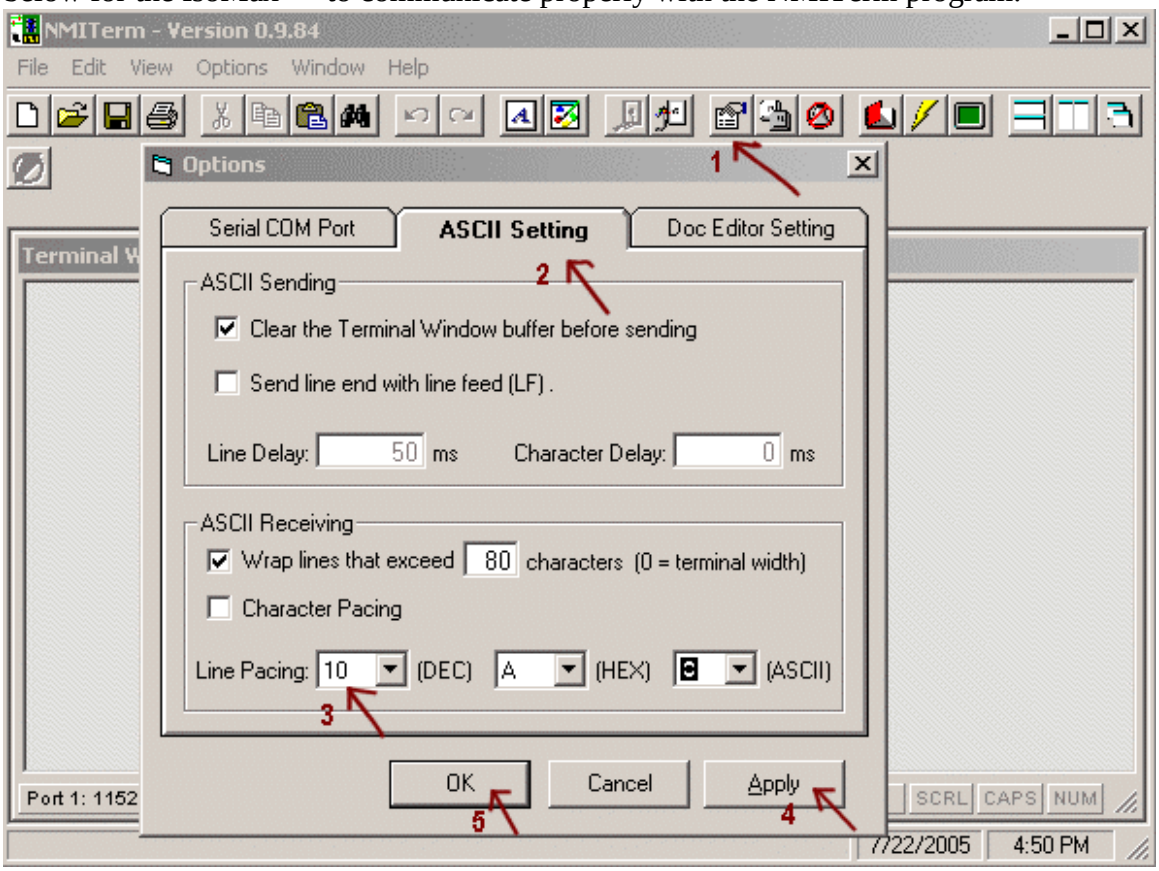

Figure 7 – NMITerm ASCII Setting for IsoMax

When the power is applied, before any user program is loaded, the PC terminal program should show,

"IsoMax™ V0.6"(or latest production version)

If the LED's don't light, and the screen doesn't show the message, unplug the power to the NMIN-0803-H6. Check the power connections. If the LED's come on but there is no

communication, check the terminal program baud rate setting. Check the serial connections. If you have no success, see the trouble shooting section of this manual and then contact technical support for help, before going further. Do not leave power on the board for more than a few seconds if it does not appear to be operational.

Normally at this point you will see the prompt on the computer screen. Odds are you're there. Congratulations! Now let's do something interactive with the NMIN-0803-H6.

In the terminal program on the PC, type in, "WORDS" (all in "caps" as the language is case sensitive), and then hit "Enter". A stream of words in the language should now scroll up the screen. Good, we're making progress. You are now talking interactively with the IsoMax language in the NMIN-0803-H6.

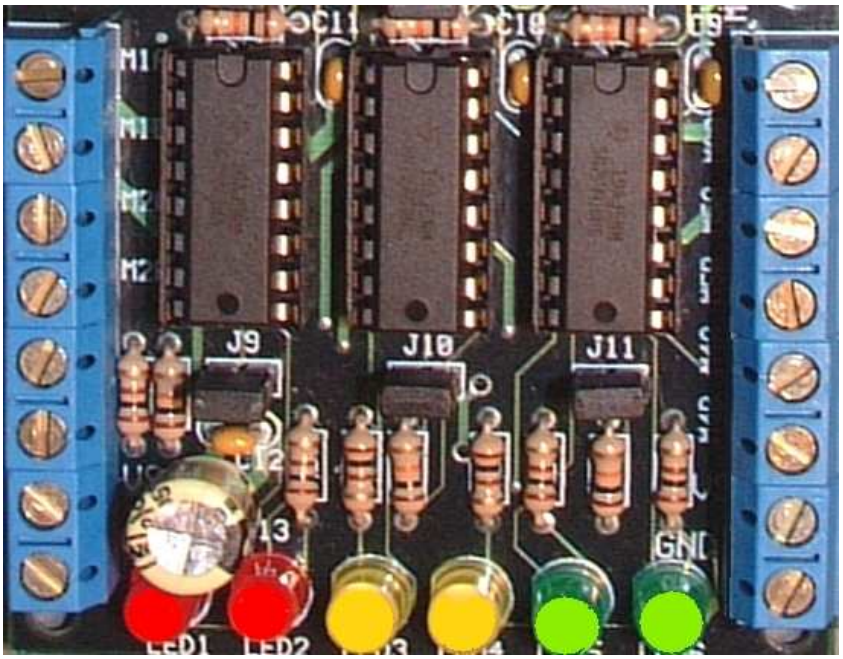

Figure 8 – H-Bridges & LEDs Section

With the IsoMax language installed. You can interactively typing the commands to blink the LED's. LED1-6 are controlled by the port lines, PA0-5 respectively.

To turn the LED1 off/on. Type:

```
PA0 OFF ( or, PA0 ON )
```

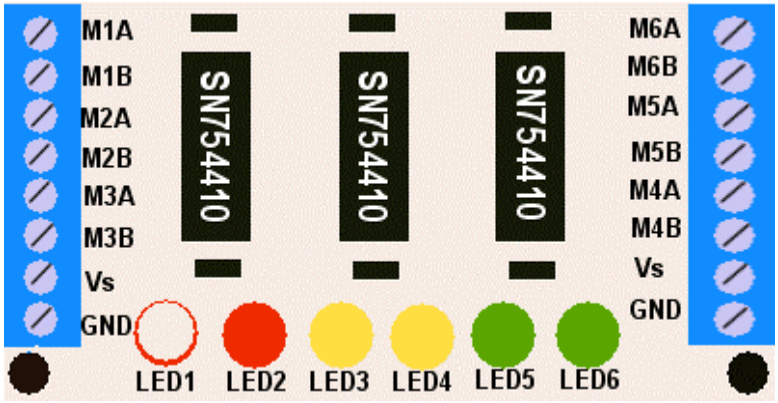

Figure 9 –LED1 off

Turn off/on LED3, type:

```
PA2 OFF ( or, PA2 ON  )
```

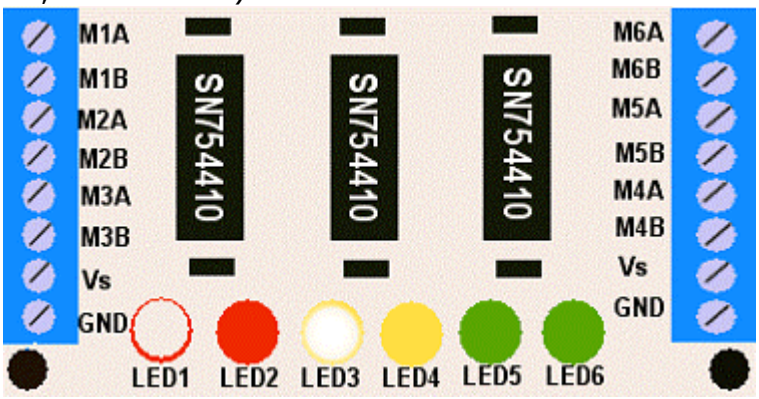

Figure 10 –LED3 off

Turn off/on LED5, type:

```
PA4 OFF ( or, PA4 ON  )
```

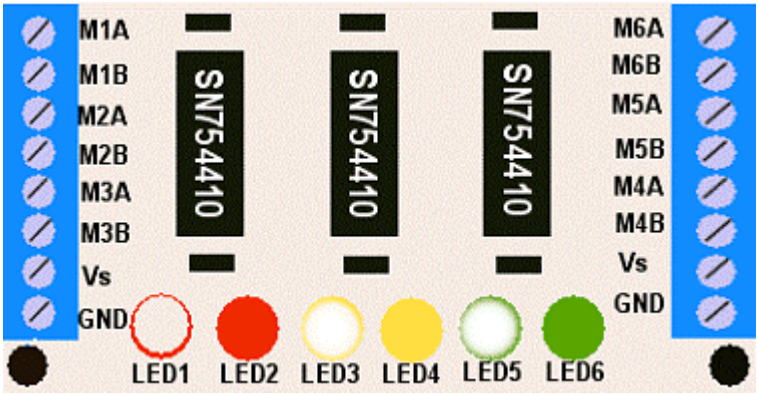

Figure 11 – Green LED5 off

Seeing the LED's responded to IsoMax commands, you should have a good feeling because you can tell your NMIN-0803-H6 is working. It's time for an overview of what your NMIN-0803-H6 has for features.

2 QUICK TOUR

Start by comparing your board to the diagram below. Most of the important features on the top board are labeled.

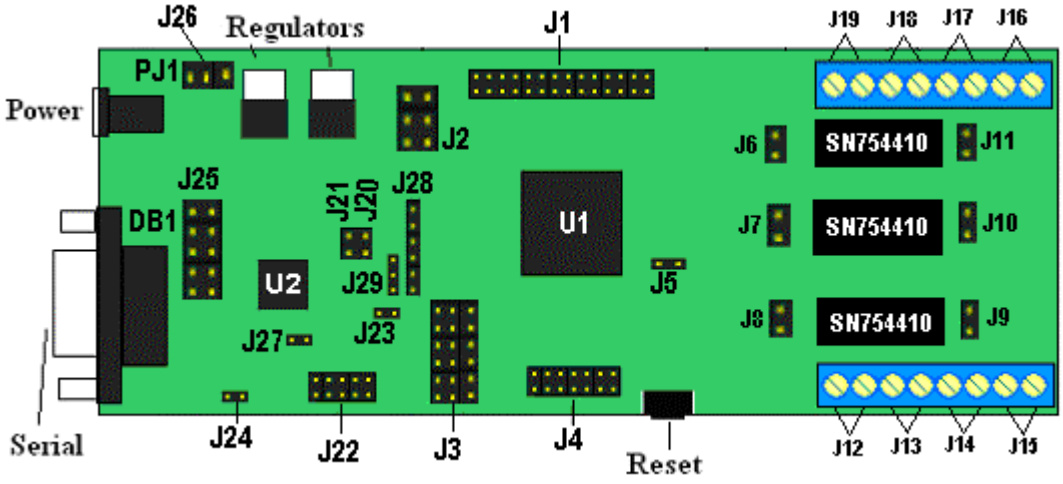

Figure 12 – Jumpers & Connectors

The features most important to you will be the connectors & jumpers. The following list gives a brief description of each connector and the signals involved.

J1	Analog inputs and unused Address & Data lines
J2	Additional Power Input pins, VIN/+5V/+3.3V/GND use for test points
J3	Timers/Encoder/Interrupts/Misc. digital inputs
J4	JTAG interface connector, 14 pin
J5	Internal/External memory Boot jumper selection. Not connected by default.
J6-11	Optional I/O controlled H-Bridge Disable/Enable jumpers. It's not connected by default. H-Bridges are enable.
J12-14, J15, J16	H-Bridge Output connectors Motor (H-Bridge) Power input connectors
J17-19	H-Bridge Output connectors
J20-21	Optional I/O controlled RS-422/485 Receiver enable/disable
J22	CAN interface connector
J23	Optional I/O controlled RS-232 transmitter Enable/Disable
J24	Optional CAN speed I/O controlled. Not connected by default
J25	Optional RS-422/485 interface connector
J26	Optional DC power input for CPU circuit
J27	Optional I/O controlled RS-232 Receiver Enable/Disable
J28	Optional Serial TTL levels & 5V & 3.3V & GND
J29	RS-232 or RS-422/485 Jumper selection for CPU serial input
DB1	RS-232 Serial DB9 connector
PJ1	CPU power supply input power jack

The table above explains the type of connection that can be made to each of the connectors. The power, reset, and ground can be used externally for various applications.

Most of the connectors are single, or dual or triple row male headers. Connection can be made with female headers with crimped wire inserts, or IDC headers with soldered or cabled wires.

Signals were put on separate connectors where possible, such as with the RS-232, the Can Bus, PWM connectors, and Data/Address line for future memory expansion.

The male headers allow insertion of individually hand-crimped wires in connectors where signals are combined. The large chip at the center of the board is the CPU (DSP56F803).

The six LED's, Red, Yellow, and Green, are along the bottom of the CPU can be used as user control, or for H-Bridges enable/disable indications.

Three 1A Dual H-Bridge, SN754410 use to drive small DC motors are located on the bottom of the board.

Onboard 5V & 3.3V voltage regulators. These regulators can handle up to 1A when use with proper heat sink.

A few smaller chips are also on the board, the RS-232 transceiver and the LED driver, CAN driver, and a handful of resistors and capacitors.

3 I/O CONNECTORS

3.1 J1, Analog inputs and spare Data & Address lines

VDD	1	2	VSS
VDDA/VREF	3	4	VSSA
AN7	5	6	AN6
AN5	7	8	AN4
AN3	9	10	AN2
AN1	11	12	AN0
D15	13	14	D14
D13	15	16	D12
D11	17	18	D10
D9	19	20	D8
D7	21	22	D6
D5	23	24	D4
D3	25	26	D2
D1	27	28	D0

J3, Timers/Encoder/Digital Inputs/Interrupts

1	VSS	2	FAULTA0	3	+3.3V
4	TA2/INDEX0	5	FAULTA1	6	GND
7	TA0/PHASEA0	8	FAULTA2	9	GND
10	+5.0V	11	ISA0	12	GND
13	TA1/PHASEB0	14	ISA1	15	IRQA
16	TA3HOME0	17	ISA2	18	IRQB

3.2 J29, RS-232/RS-422/485 selecttion

1	U2-ROUT	2	U1-RxD0	3	U4-ROUT

RS-232 Receiver output: Jumper on pin 1 & 2 by default,
RS-422/485 Receiver output: Jumper on Pin 2 & 3. U3 & U4 need to be populated.

3.3 J22, CAN Connector

N.C.	CANH	N.C.	N.C.	N.C.
2	4	6	8	10
1	3	5	7	9
N.C.	CANL	GND	N.C.	N.C.

3.4 J24, CAN Speed Controls

S, Pin 8	1	2	TD2

Unconnected: for normal operation (by default)
CAN speed can be controlled by TD2. Pin 1 & 2 are connected

3.5 J4, JTAG connector

GND	GND	GND	NC	TMS	DE	TRST
2	4	6	8	10	12	14
1	3	5	7	9	11	13
TDI	TDO	TCK	NC	RESET	3.3 V	NC

3.6 J25, RS-422/485 Connector

NC	-RCV(-485)	GND	+XMT	NC
9	7	5	3	1
10	8	6	4	2
NC	+RCV(+485)	GND	-XMT	NC

3.7 J20 & J21, RS-422 or RS-485 selection

RS-485 configuration, Jumper J20 needs to be connected. J21 is opened.

RS-422 configurations:

- Receiver Output always enable. Jumper J21 is connected. J20 is opened.
- Receiver Output controlled by port TD1. J20 is connected, J21 is opened.

4 CIRCUIT DESCRIPTION

The processor chip contains the vast majority of the circuitry. The remaining support circuitry is described here. The power for the system can be handled several different way, but as the board comes, CPU power will normally be supplied from the PJ1 power jack with either AC or DC supply. A wall transformer output from 8V to 12V at 300mA or higher is suggested.

4.1 RS-232 Levels Translation

The MAX3221/6/7 converts the 3.3V supply to the voltages necessary to drive the RS-232 interface. Power shutdown feature is provided using the I/O's control signals PE2 and TD1. By default, the Max3221 is configured for normal operation with the pull-up/down resistors installed on ForceOff'/En' pin respectively. More information on power shutdown please see the link below,
http://pdfserv.maxim-ic.com/arpdf/MAX3221-MAX3243.pdf

4.2 CAN BUS Levels Translation

The CAN transceiver is configured for high speed mode at default. To use the speed control, jumper J24 must connected. Where an I/O port TD2 is assigned to use for this purpose. TD2 turns OFF/ON to toggle between the high speed mode and the silence mode respectively. Please see the link below for more info on CAN transceiver TJA1050,
http://www.nxp.com/acrobat_download/datasheets/TJA1050_4.pdf

4.3 LED's

An 74AC05 drives the on-board LED's. Each LED has a current limiting resistor to the +3.3V supply. PA0-5 are assigned for the LED's control. Output a high signal on port pin will turn on the LED. And output low on port pin will turn off the LED.
http://focus.ti.com/lit/ds/symlink/cd74ac05.pdf

4.4 RESET

A S80728HN Low Voltage Detector asserts reset when the voltage is below operating levels. This prevents brown out runaway, and a power-on-reset function.
http://www.seiko-instruments.de/documents/ic_documents/power_e/s807_e.pdf

4.5 H-BRIDGE Drivers

There are three SN754410, quadruple high-current half-H driver on the NMIN-0803-H6. The SN754410 is a quadruple high-current half-H driver designed to provide bidirectional drive currents up to 1 A at voltages from 4.5 V to 36 V. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

See link below for more info on the H-Bridge, SN754410
http://focus.ti.com/lit/ds/symlink/sn754410.pdf

4.6 POWER SUPPLY

A MC7805 provides 5V power for CAN bus driver, Quadrature Encoder, H-Bridges digital circuit supply, and to drop the 5V to the 3.3V needed for the processor and leds. Also at full current 270 mA, these two regulators will get warm. They can provide current to external circuits if care is taken to keep them cool. Each are rated at 1A but will have to have heat sinking added to run there.

5V regulator data sheet,
http://www.onsemi.com/pub/Collateral/MC7800-D.PDF

3.3V regulator data sheet,
http://www.national.com/ds/LM/LM3940.pdf

5 TROUBLE SHOOTING

There are no user serviceable parts on the NMIN-0803-H6. If connections are made correctly, operation should follow, or there are serious problems on the board. As always, the first thing to check in case of trouble is checking power and ground are present. Measuring these with a voltmeter can save hours of head scratching from overlooking the obvious. After power and ground, signal connections should be checked next. If the serial cable comes loose, on either end, using your PC to debug your program just won't help. Also, if your terminal program has locked up, you can experience some very "quiet" results. Don't overlook these sources of frustrating delays when looking for a problem. They are easy to check, and will make a monkey of you more times than not, if you ignore them.

One of the great advantages of having an interactive language embedded in a processor, is if communications can be established, then program tools can be built to test operations. If the RS-232 channel is not in use in your application, or if it can be optionally assigned to debugging, talking to the board through the language will provide a wealth of debugging information.

The LED's can be wonderful windows to show operation. This takes some planning in design of the program. A clever user will make good use of these little light. Even if the RS-232 channel is in use in your application and not available for debugging, don't overlook the LED's as a way to follow program execution looking for problems.

The NMIN-0803-H6 is designed so no soldering to the board should be required, and the practice of soldering to the board is not recommended. Instead, all signals are brought to connectors.

So, the best trouble shooting technique would be to unplug the NMIN-0803-H6 and try to operate it separately with a known good serial cable on power supply.

If the original connections have been tested to assure no out-of-range voltages are present, a second NMIN-0803-H6 can then be programmed and plugged into the circuit in question. But don't be too anxious to take this step. If the first NMIN-0803-H6 should be burned out, you really want to be sure you know what caused it, before sacrificing another one in the same circuit.

Finally, for advanced users, the JTAG connection can give trace, single step and memory examination information with the use of special debugging hardware. This level of access is beyond the expected average user of the NMIN-0803-H6 and will not be addressed in this manual.

6 Embedded Software Development

6.1 Overview

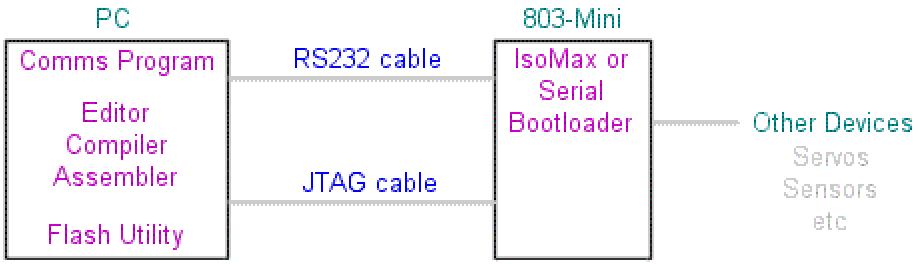

Figure 2 – Embedded Software Development Overview

This diagram shows all of the components available for embedded software development. Note that not all of the components will be used, depending upon the scheme adopted by the developer. These schemes – and the required components – are detailed below.

6.2 IsoMax

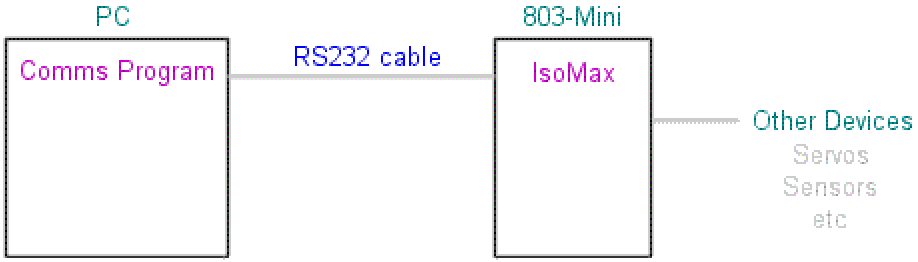

Figure 3 – Software Development using IsoMax

In this configuration, the PC user runs a program which communicates with IsoMax via the RS-232 cable. This allows interactive software development and testing. Details of IsoMax can be found on NMI's website.

6.3 Compiler & Assembler

Using this method, software is developed on the PC and transferred to the 803-H6 using either the RS-232 (serial) cable or a JTAG cable. Note that the diagrams, below, show the components *required* for each scheme. Additional components are optional.

6.3.1 With JTAG

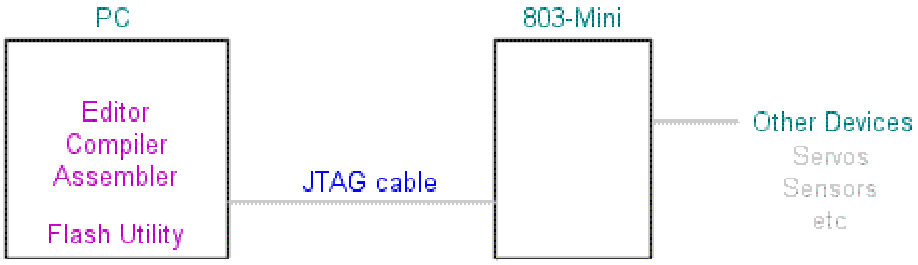

Figure 4 – Software Development using JTAG

In this configuration, an editor is used to write a program on the PC, which is then compiled, assembled, and transferred to the 803-H6 via the JTAG cable using a Flash Utility on the PC. The RS-232 cable and communications program (not shown) are optional.

The JTAG cable plugs into the PC's parallel port, and J6 on the 803-H6 board. However, the Windows Operating System does not allow a 'normal' user program – like the Flash Utility - to directly control the computer's hardware (i.e. the parallel port), so a utility must be used which permits this, such as UserPort.

6.3.2 With Serial Bootloader

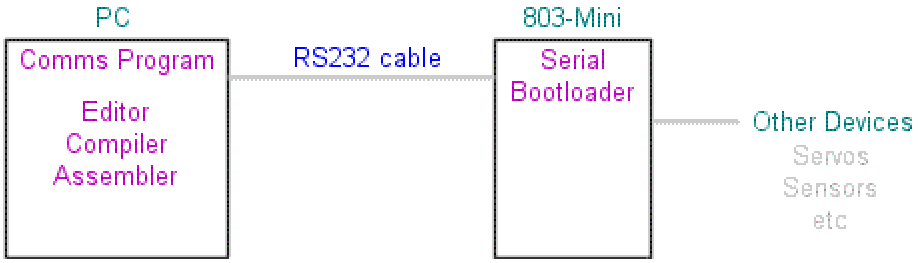

Figure 5 – Software Development using Serial Bootloader

In this configuration, an editor is used to write a program on the PC, which is then compiled, assembled, and transferred to the 803-H6 via the RS-232 cable using the Communications Program on the PC and the Serial Bootloader software on the 803-H6. The JTAG cable and Flash Utility (not shown) are optional.

7 PC Communication

A variety of programs are available which allow a PC to communicate directly with the NMIN-0803-H6. These programs are sometimes referred to as 'Communications Programs', 'Comms programs' or 'Terminal Programs' (because some emulate Computer Terminals). These programs run on the PC and are used in conjunction with an RS-232 cable, also known as a Serial Cable. One end of this cable plugs into the PC's COM port, and the other end is for the 803-H6's RS-232 connector, DB1.

Note: The settings given in the following sections are IsoMax and JTAG users only – Serial Bootloader users should refer to the relevant sections in this manual for the required settings.

7.1 NMITerm

Provided Windows terminal program from New Micros, Inc. Usually provided in a ZIP. Un ZIP in a subdirectory, such as C:\NMITerm. To start the program: click, or double click, the program icon.

NMITerm is a simple Windows-based communications package designed for program development on serial port based embedded controllers. It runs under Windows.

NMITerm provides:

1. Support for COM1 through COM16.
2. Baud rates from 110 through 256000.
3. Control over RTS and DTR lines.
4. Capture files, which record all terminal activity to disk.
5. Scroll-back buffer, editable and savable as a file.
6. On-line Programmer's Editor.
7. File downloader.
8. Programmable function keys.

Quick start commands:

1. Baud: default 115200
2. DTR On/Off : ALT+T
3. Download: ALT+D

For further information use the F1 Help screen.
This program can be downloaded from:
http://www.newmicros.com/download/NMITerm.zip

7.2 HyperTerminal

Usually provided in Programs/Accessories/Communications/HyperTerminal. If not present, it can be loaded from the Windows installation disk. Use “Add/Remove Software” feature in Settings/Control Panel, choose Windows Setup, choose Communications, click on Hyperterm, then Okay and Okay. Follow any instructions to add additional features to windows.

C:\Program Files\Accessories\HyperTerminal

Run HyperTerminal, select an icon that pleases you and give the new connection a name, such as H3803. Now in the “Connect To” dialog box, in the bottom “Connect Using” line, select the communications port you wish to use, with Direct Com1, Direct Com2, Direct Com3, Direct Com4 as appropriate, then Okay. In the COMx Dialog box which follows set up the port as follows: Bits per second: 115200 , Data bits: 8, Parity: None, Flow Control: None, then Okay.

The ATN signal must be unconnected when using this program. There is no option to remotely set and reset the board using the DTR line with this program.

8 Suggested Readings

IsoMax reference,
http://www.newmicros.com/store/product_manual/IsoPod.pdf

DSP56F80x CPU manual,
http://www.freescale.com/files/dsp/doc/user_guide/DSP56F801-7UM.pdf

DSP56F803 Technical data
http://www.freescale.com/files/dsp/doc/data_sheet/DSP56F803.pdf

9 Online Resources

9.1 NMIN-0803-H6 website

http://www.newmicros.com/cgi-bin/store/order.cgi?form=prod_detail&part=NMIN-0803-H6

9.2 Small C & Assembler website

http://petegray.newmicros.com/

9.3 IsoMax™ Documents & Examples

http://www.newmicros.com/store/product_details/download.html

9.4 Freescale DSP56F801-7 Users Manual

http://www.freescale.com/files/dsp/doc/user_guide/DSP56F801-7UM.pdf

9.5 Freescale DSP56F800 Processor Reference Manual

http://www.freescale.com/files/dsp/doc/ref_manual/DSP56800FM.pdf

9.6 Freescale DSP56F803 Technical Data

http://www.freescale.com/files/dsp/doc/data_sheet/DSP56F803.pdf

10 MANUFACTURER

New Micros, Inc.
1601 Chalk Hill Rd.
Dallas, TX 75212

Tel: (214) 339-2204
Fax: (214) 339-1585

Web site: http://www.newmicros.com

This manual: http://www.newmicros.com/store/product_manual/NMIN-0803-H6.pdf

Email technical questions: techsupport@newmicros.com

Email sales questions: nmisales@newmicros.com

11 MECHANICAL

Board size is 2.3” x 6.3”

DB1 adds .3” to total board length.

12 ELECTRICAL

Table 1 – DSP56F80x Absolute Maximum Ratings

Characteristic	Symbol	Min	Max	Unit
Supply voltage	V_{DD}	V_{SS} – 0.3	V_{SS} + 4.0	V
All other input voltages, excluding Analog inputs	V_{IN}	V_{SS} – 0.3	V_{SS} + 5.5V	V
Analog Inputs ANAx, V_{REF}	V_{IN}	V_{SS} – 0.3	V_{DDA} + 0.3V	V
Current drain per pin excluding V_{DD}, V_{SS}, PWM outputs, TCS, V_{PP}, V_{DDA}, V_{SSA}	I	—	10	mA
Current drain per pin for PWM outputs	I	—	20	mA
Junction temperature	T_J	—	150	℃
Storage temperature range	T_{STG}	-55	150	℃

Table 2 - Recommended Operating Conditions

Characteristic	Symbol	Min	Max	Unit
Supply voltage	V_{DD}	3.0	3.6	V
Ambient operating temperature	T_A	-40	85	℃

Table 3 - DC Electrical Characteristics

Operating Conditions: $V_{SS} = V_{SSA} = 0$ V, $V_{DD} = V_{DDA} = 3.0–3.6$ V, $T_A = –40°$ to $+85°C$, $C_L \leq 50$ pF, $f_{op} = 80$ MHz

Characteristic	Symbol	Min	Typ	Max	Unit

Input high voltage	V_{IH}	2.0	—	5.5	V
Input low voltage	V_{IL}	-0.3	—	0.8	V
Input current low (pullups/pulldowns disabled)	I_{IL}	-1	—	1	µA
Input current high (pullups/pulldowns disabled)	I_{IH}	-1	—	1	µA
Typical pullup or pulldown resistance	R_{PU}, R_{PD}	—	30	—	KΩ
Input/output tri-state current	low I_{OZL}	-10	—	10	µA
Input/output tri-state current	low I_{OZH}	-10	—	10	µA
Output High Voltage (at IOH)	V_{OH}	V_{DD} – 0.7	—	—	V
Output Low Voltage (at IOL)	V_{OL}	—	—	0.4	V
Output High Current	I_{OH}	—	—	-4	mA
Output Low Current	I_{OL}	—	—	4	mA
Input capacitance	C_{IN}	—	8	—	pF
Output capacitance	C_{OUT}	—	12	—	pF
PWM pin output source current 1	I_{OHP}	—	—	-10	mA
PWM pin output sink current 2	I_{OLP}	—	—	16	mA
Total supply current	I_{DDT} 3				
Run 4		—	126	162	mA
Wait 5		—	72	98	mA
Stop		—	60	84	mA
Low Voltage Interrupt 6	V_{EI}	2.4	2.7	2.9	V
Power on Reset 7	V_{POR}	—	1.7	2.0	V

1. PWM pin output source current measured with 50% duty cycle.

2. PWM pin output sink current measured with 50% duty cycle.

3. $I_{DDT} = I_{DD} + I_{DDA}$ (Total supply current for $V_{DD} + V_{DDA}$)

4. Run (operating) I_{DD} measured using 8MHz clock source. All inputs 0.2V from rail; outputs unloaded. All ports configured as inputs; measured with all modules enabled.

5. Wait I_{DD} measured using external square wave clock source (f_{osc} = 8 MHz) into XTAL; all inputs 0.2V from rail; no DC loads; less than 50 pF on all outputs. C_L = 20 pF on EXTAL; all ports configured as inputs; EXTAL capacitance linearly affects wait I_{DD}; measured with PLL enabled.

6. Low voltage interrupt monitors the V_{DDA} supply. When V_{DDA} drops below V_{EI} value, an interrupt is generated. For correct operation, set V_{DDA}=V_{DD}. Functionality of the device is guaranteed under transient conditions when V_{DDA}>V_{EI}.

7. Power-on reset occurs whenever the internally regulated 2.5V digital supply drops below V_{POR}. While power is ramping up, this signal remains active for as long as the internal 2.5V supply is below 1.5V no matter how long the ramp up rate is. The internally regulated voltage is typically 100 mV less than V_{DD} during ramp up until 2.5V is reached, at which time it self regulates.