NMIN-12A256B
Single Board Computer
User Manual V.1

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1.0 Overview

The NMIN-12A256B single board computer provides you with plug and play access to a powerful microcontroller. The computer board provides power regulation, RS232 and RS422 serial support and an LCD connector. The microcontroller includes the following built in capabilities:

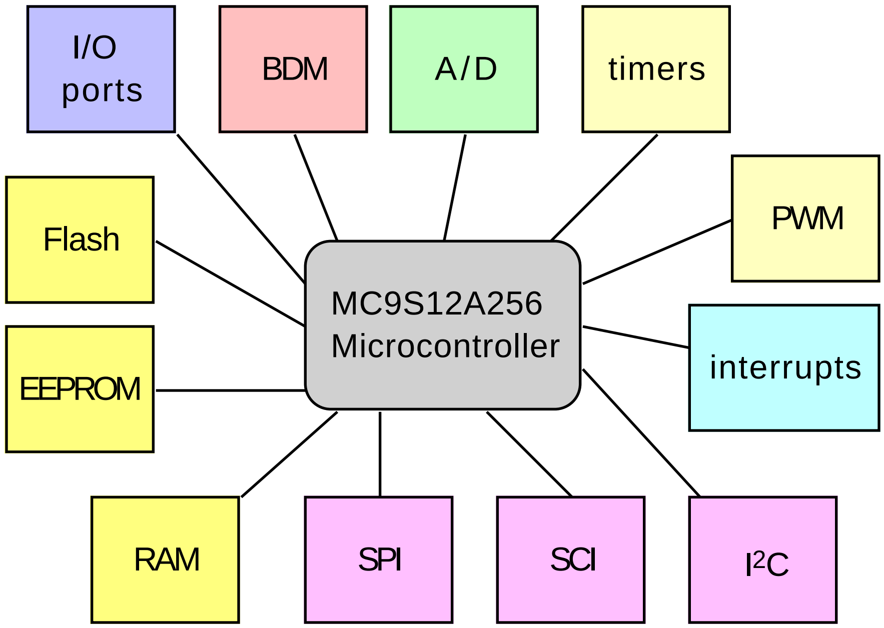


Figure 1 Peripheral interfaces on the MC9S12A256 microcontroller.

1.1 Noted microcontroller features:

- 16-bit HCS12 CPU
- Multiplexed External Bus Interface for memory expansion
- Interrupt control for all onboard peripherals including priority manipulations
- Breakpoints for stepping through code without needing an emulator
- Single-wire BDM (Background Debug Mode) for downloading and debugging
- low current oscillator, PLL, COP watchdog, real time interrupt, clock monitor
- 8-bit and 4-bit ports with interrupt functionality
- Programmable rising or falling edge triggers
- 256K Flash EEPROM
- 4K byte EEPROM
- 12K byte RAM
- 8-channel 10-bit 5V Analog-to-Digital Converters
- 16-bit counter/timer with 8 programmable input capture or output compare channels
- Two 8-bit or one 16-bit pulse accumulators
- 8 PWM channels
- Two asynchronous Serial Communications Interfaces (SCI) up to 115K baud
- Three Synchronous Serial Peripheral Interface (SPI)
- Inter-IC Bus (IIC) compatible with I^{2}C Bus standard
- I/O lines with 5V input and drive capability
- Operation at up to 50MHz for core and up to 25MHz bus speed for peripherals
- Single-Chip and Expanded Modes
- Low power modes

The computer board’s power consumption is about 60 mA.

1.2 Included Files

The following files are included and are available from our website. The MaxForth files are only available if you have licensed them:

- as12 - Mac OS X version of the Motorola freeware assembler
- as12.exe - PC version of the Motorola freeware assembler
- as12.htm - documentation for the assembler
- BootEVB-16.S19 - Serial Boot loader, srecord file
- DB12DP256-16.S19 - Dbug12 monitor, srecord file
- HCS12Manuals.zip - contains a copy of the Motorola manuals for the microcontroller from their website. Note: these are too big to put on a Floppy so they are available at: **http://www.ee.ualberta.ca/~rchapman/MFwebsite/HCS12/HCS12Manuals.zip**
- NMIN-12A256Bv1.pdf - this manual in PDF format
- Out.S19 - output of converted srecord
- rtiled.lst - output of assembled source code
- rtiled.s - source code example of an interrupt and power saving instruction WAI
- rtiled.s19 - srecord output from assembler
- SRecCvt (OSX) - srecord conversion utility for Mac OS X
- SRecCvt.exe - srecord conversion utility for PCs
- SRecCvtRG.pdf - srecord conversion utility documentation

Licensed files:

- fuzzytest.f - an example file for testing the fuzzy logic support
- mf51fhcs12.map - contains a map of all the bits and pieces in MaxForth for the current release but may change in future releases. Use with caution.
- MF51FHCS12.S19 - a copy of the MaxForth kernel in Motorola S-record form that can be downloaded when experimenting with flash
- SCRUB.F - a utility for clearing vectors from EEPROM and flash
- SHT11.F - an example of interfacing to a temperature and humidity sensor
- TESTA24.F - an example to test ATO4

NOTE: Throughout the manual, 0x is used to precede hex addresses in the text for clarity but it is not used in the MaxForth examples because the numeric base is changed by typing HEX or DECIMAL.

2.0 Getting Started

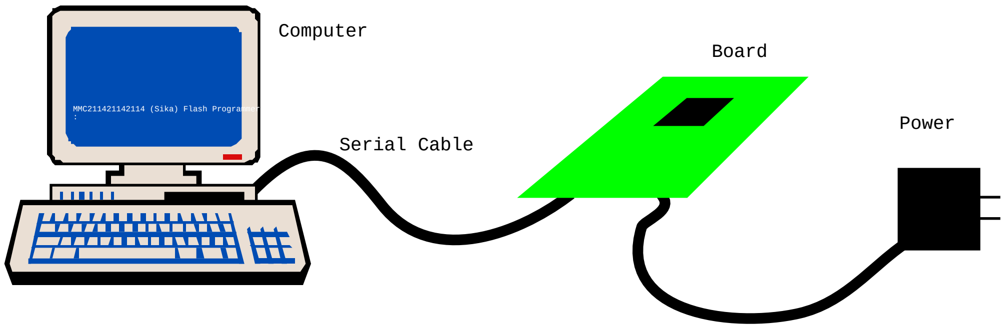


Figure 2 Computer hooked up to board with a serial cable.

You will interact with your board by connecting it to a PC using a serial cable and running a terminal program such as HyperTerminal or an equivalent setup. You need to set it to 9600 BAUD, one stop bit, no parity and 8 data bits. Connect an RS232 serial cable between your PC's COM port and the serial port on the board. To power up the board, you need a 7 to 12 volt plug-in transformer plugged into the power jack, PJ1 (AC, DC both polarities accepted).

Alternatively, you could use Linux or a Mac. On the Mac, ZTerm is a powerful terminal program available as shareware from the Internet.

When everything is ready and you plug in the power, you should receive a prompt in the terminal program. If you have the J4 jumpers set to the serial loader position:

```
D-Bug12 Bootloader v1.0.0

a) Erase Flash
b) Program Flash
c) Set Baud Rate
d) Erase EEPROM
?
```

or if the J4 jumpers are set to the application position and the D-Bug12 monitor application is loaded:

```
D-Bug12 4.0.0b18
Copyright 1996 - 2002 Motorola Semiconductor
For Commands type "Help"

>
```

or if the J4 jumpers are set to the application position and MaxForth is loaded:

`Max-FORTH V5.1F` (license agreement is required)

And when you depress the ENTER key, it should respond with

```
 type ? for help
:
```

or

```
>
```

or

`OK` (Max-FORTH prompt)

When you see that message, it means the communication is established and you are ready to interact with the board and microcontroller. By pressing the reset button, RS1, you should get the same boot prompt as when you powered it up. Pressing the reset button will leave the contents of most of the RAM intact which might be useful for debugging purposes, whereas, if you power cycle the board, then all RAM contents will be lost.

3.0 Memory Map

The memory map consists of RAM, ROM and registers. The interrupt vectors exist in protected flash space along with the serial loader. Since they can't be changed, a secondary vector table exists at 0xEF80. There is a one to one correspondence with the primary vector table. Since these locations can only be written once, the entire 512 bytes must be erased to change a vector. For prototyping, the vector can be set once to point into EEPROM which can be erased more easily.

When only the serial loader is loaded, it relocates RAM to the top of memory and copies itself to it to run only out of RAM. This allows the changing of page F through the flash window at 0x8000. The MaxForth system takes up space in page E and page F of flash leaving pages 0 to page D available for use. None of the EEPROM is used so it is all available for use for user applications.

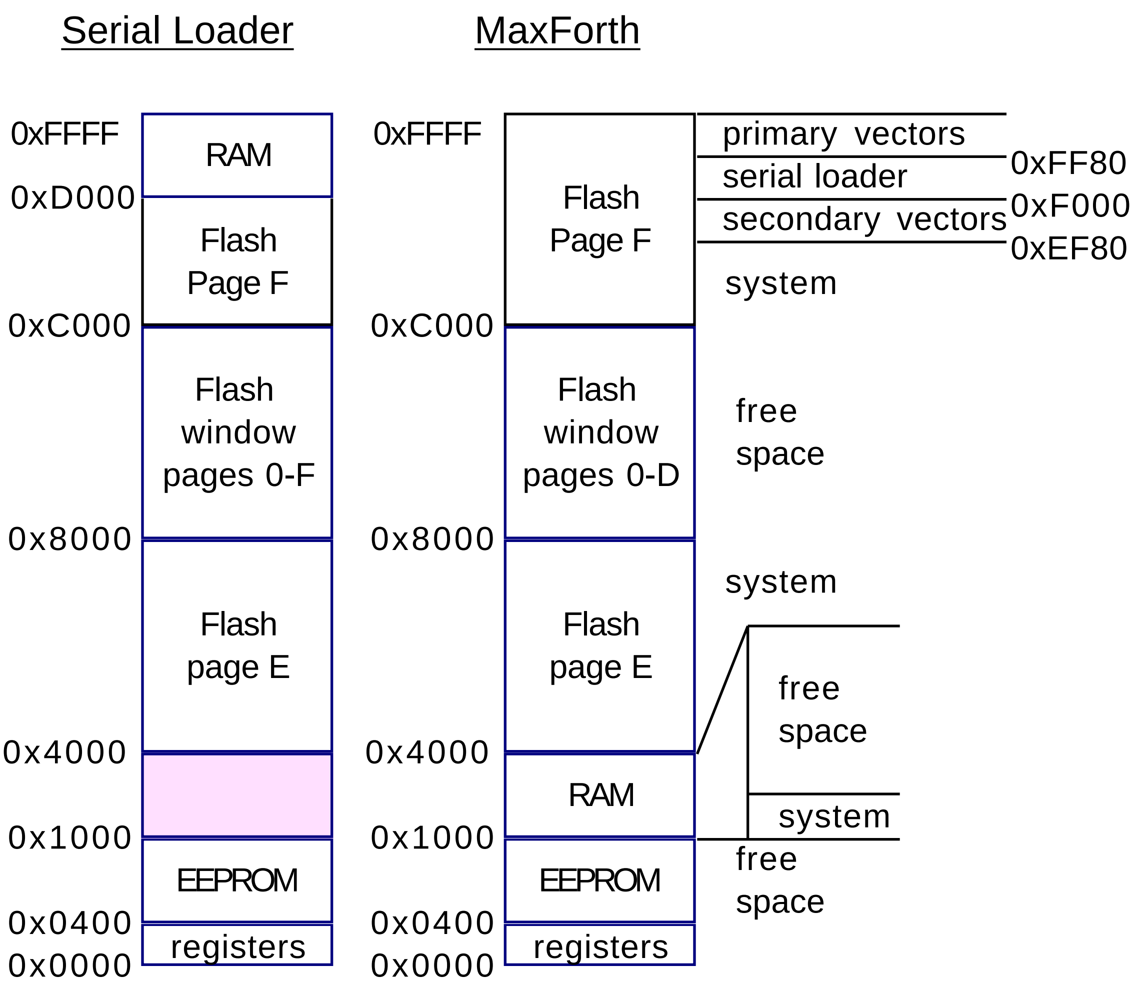


Figure 3 After booting, the RAM memory map either belongs to the serial loader or the MaxForth application.

4.0 Programming the Board

When the board is reset, it executes the program pointed to by the vector at location 0xFFFE. In a loaded board this will be the boot loader which will either start the serial loader or MaxForth. When MaxForth starts, it checks to see if there is an autostart application present and runs it or else it just runs MaxForth.

There are several ways in which to program the board:

1. download an s-record through the BDM connector and the PC parallel port using a programmer

such as P&E Micro's BDM programmer.

2. download s-records using the embedded serial loader and a serial port with HyperTerminal, NMITerm or equivalent
3. interact directly with the microcontroller and download source code to the on-board development system, MaxForth, through a serial port and HyperTerminal

When downloading text files to the board, using the text download protocol, make sure the delay per line is at least 100 milliseconds. You can risk having lines missed if you go to fast, but with some setups, it is possible to use smaller line delays which has a nice effect on a long download. Your mileage will vary.

4.1 BDM Connector and Parallel Port

Using the HCS12 cable from P&E Micro or equivalent, plug it into the parallel port of your computer through a parallel port cable and the BDM port on the computer board making sure to orientate the triangle on the pin header to pin 1 on the board which is marked by a square solder pad on the bottom of the board. Apply power to the board. When disconnecting from the board make sure it goes through a power cycle before you try out the downloaded software since a reset is not enough to regain control of the microcontroller after interacting with the BDM port.

Check the help screens for more details.

4.2 S-Records and the Serial Loader

Using the serial loader, you can download s-records that have been created by a C compiler or Assembler program that you have acquired separately, to flash memory to be run. The help menu, invoked by typing a ?, is:

```
? ?

a) Erase Flash
b) Program Flash
c) Set Baud Rate
d) Erase EEPROM
?
```

The serial loader works by running out of RAM. At bootup, the boot program in flash checks to see if there is an application by checking for a vector at 0xEFFE. If there isn't, then it copies the serial loader program from flash to RAM and then runs the program. The serial loader program must run out of RAM to be able to program flash memory.

If you download an application, reboot and nothing happens, you can recover to the serial loader by setting the jumpers on the J4 connector with a jumper or equivalent and pressing the reset button. You will be taken back to the serial loader where you can erase your errant application and try again.

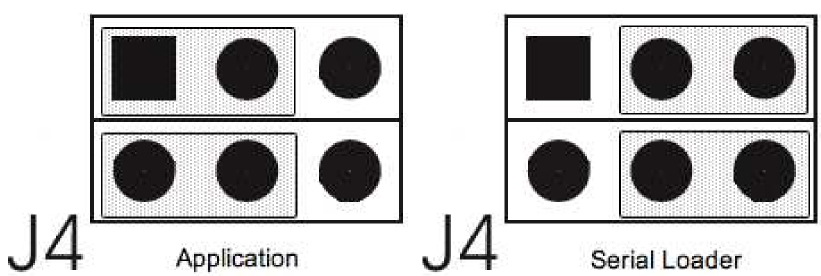


Figure 4 Jumper positions on the J4 connector for booting into the serial loader or an application. If there are no jumpers, then the default will be the Application. This is important if you intend to use channel 0 and 1 of the A/D input since leaving jumpers in the Application position will prevent those inputs from being used.

4.2.1 Downloading S-Records

The serial loader uses a simple text transfer protocol to transfer data from the host computer to the board. Depending on your host program and its defaults, the setting may be not right. Try it first and if it doesn't work, modify some of the settings.

To install a fresh copy of MaxForth and erase all the flash, do the following:

1. get to the serial loader from Forth by FLASH or by resetting with the J4 connector set like in Figure 4.
2. press a
3. wait till done, then press b
4. download the MaxForth s-record with the text protocol, by cutting and pasting or dragging and dropping if supported
5. wait till done, then press reset with the J4 jumpers removed or in the Application position

Quick Tip !! For an extremely fast download, you could try setting the baud rate to 115200, set line delay to zero and flow control to X-ON/X-OFF. Using this setup, you can download the entire kernel in seconds when needed. You could also use this method to download s-records to flash for code to be autostarted or run from MaxForth.

4.3 On-board Development System

Taking advantage of the interactive nature of the board's development system, MaxForth, you can interact directly with the microcontroller's peripherals by fetching and storing values to the memory mapped configuration registers for the peripheral devices. This is an effective way of understanding the peripheral documentation, verifying correct initialization sequences, running some tests on different configurations and debugging driver code as you develop it. By typing in new definitions, you can add new macros to the dictionary for interactive use or for creating an automated program. Some examples are given later on.

4.3.1 Hooking Into Autoboot

You can autoboot an application by leaving a vector to it at location 0xEFFE. The startup boot loader will detect this vector and then jump to the location that the vector is pointing to. When MaxForth is installed, it has a vector at that location. To get to the serial loader from MaxForth, type in FLASH and hit enter. To get back to the serial loader from an application, jump to location 0xF02E in memory. The application area can be erased using the serial loader without the boot loader being removed from memory.

MaxForth occupies the space from 0x4000-0x7FFF and 0xC000-0xC911. At location 0xEFFE is the start vector for MaxForth which is what the bootloader looks for when booting. MaxForth can be replaced by erasing it and writing a new application in its place, making sure that the startup vector for the new application is at 0xEFFE.

If you want to hook into the MaxForth autoboot system, then there are several places where you can do this:

- quick entry - allow setting of COP and other write-once registers on the micro.
- boot entry - MaxForth has been setup and can be augmented
- auto vector - last possible chance before Forth is started up

Table 1: Noted Memory Locations for Startup Hooks

Name	Value	Notes
quick_tag	0x0FEC	store a tag[1]
quick_vector	0x0FE8	CFA of word to call
boot_tag	0x0FE0	store a tag[2]
boot_vector	0x0FE4	CFA of word to call
boot_start	0x0400	lower limit in flash for checking for an auto vector tag[2] on a 1K boundary
boot_end	0xF000	upper limit of flash for auto vector tag[2] checking

1. A55A
2. A44A for first autostart or A55A for continuous last autostart.

4.3.2 Tags

The patterns `0xA44A` and `0xA55A` are referred to as tags and are used during the autoboot process to find vectors to be executed during the bootup process. Only the lowest A44A and A55A tag will be executed with A44A going first. This applies to the boot entry and autovectors. The quick entry, if used, only uses A55A.

4.3.3 Quick Entry

Quick entry lets you get in on the boot process and set COP or any other write once registers before MaxForth starts up. The tag contains a bit value that is checked first and if present, then the CFA stored at the vector preceding it is executed.

```
HEX A55A FEC EE!  ' COP-RUN CFA FE8 EE!  ( hook into quick entry vector )
```

4.3.4 Boot Entry

Boot entry lets you take over or execute something after MaxForth has been initialized. This is a good time to modify the dictionary linkage to add extra words from flash. The vector follows the tag.

```
HEX A44A FE0 EE!  ' STARTUP CFA FE4 EE!  ( hook into boot-start vector )
```

4.3.5 Auto Vector

As well, at any 1K boundary in RAM, EEPROM or flash you can lay down a tag followed by a vector.

```
HEX 1000 AUTOSTART STARTUP ( hook into auto-start vector )
```

5.0 I/O Connections and Jumpers

The jumpers and I/O headers from the board are as follows:

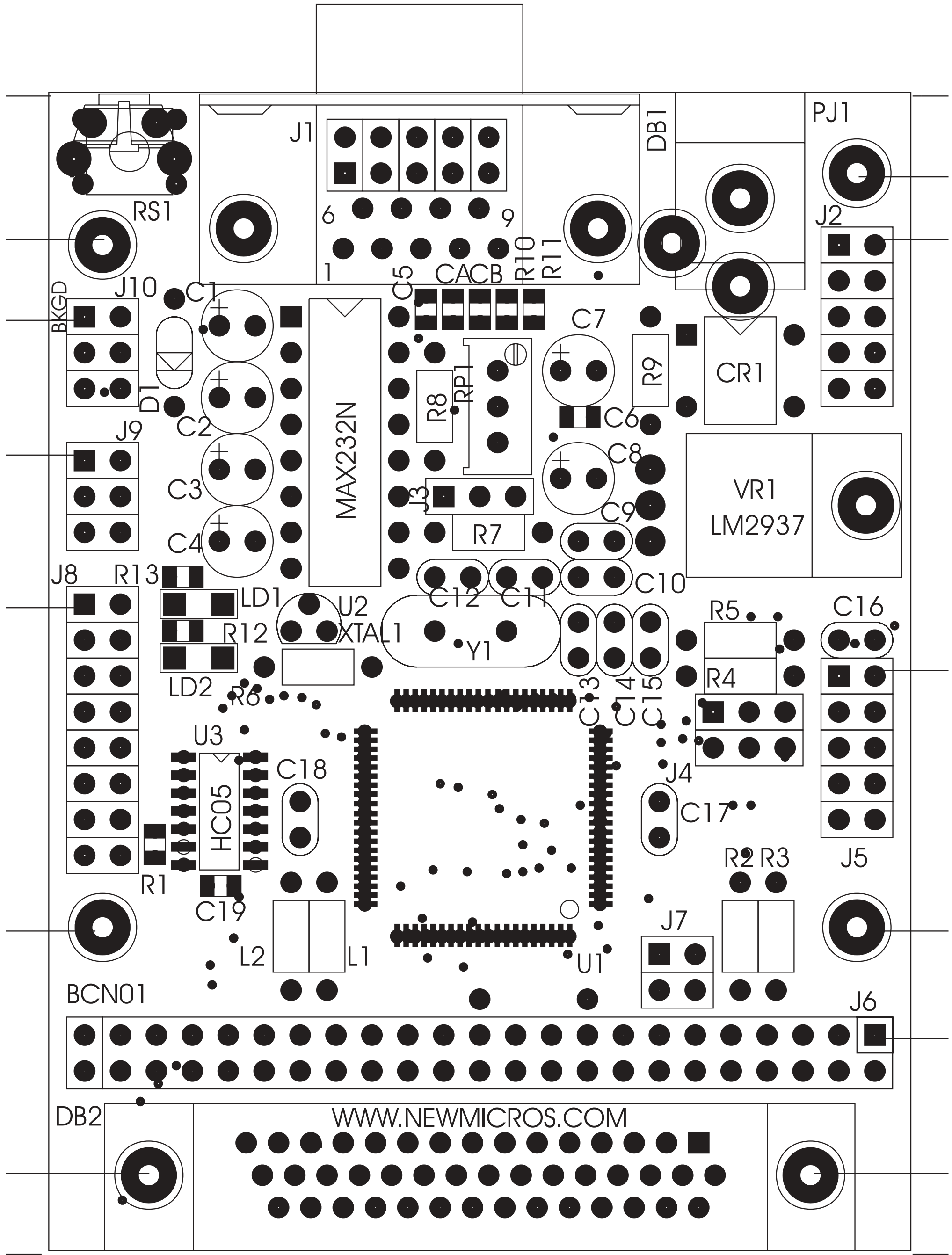
- J1 is the primary serial port, SC0, that is used for the serial bootloader, dbug12 monitor and MaxForth
- J2 is the second serial port, SCI1.
- J3 is the jumper for LCD contrast.
- J4 is for selecting boot to Serial Loader or application such as MaxForth
- J5 is the analog input header
- J6 is the I/O and other peripheral interface signals
- J7 is the jumpers for future memory expansion

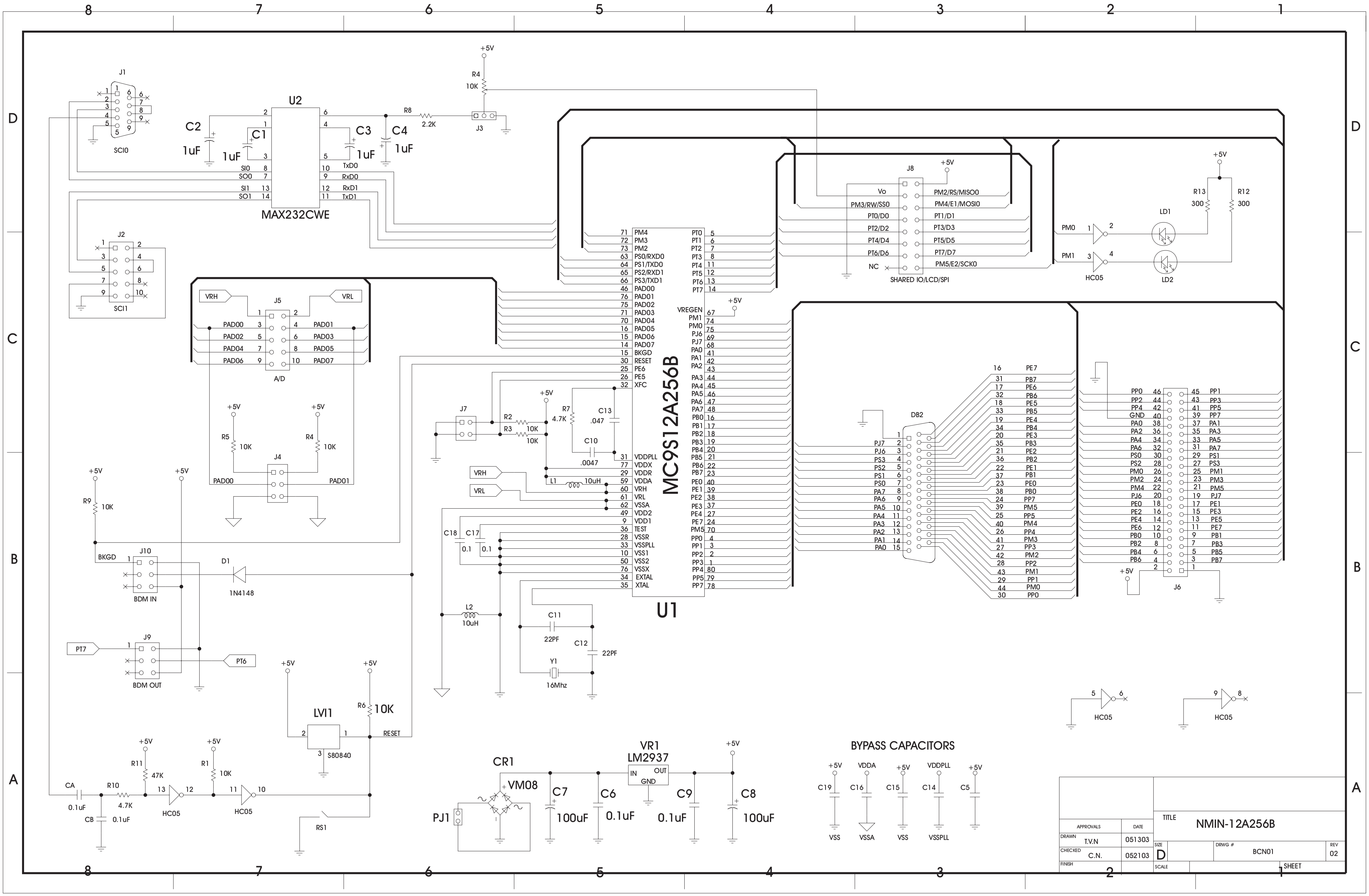
- J8 is the LCD connector, or SPI, or Timers shared I/Os
- J9 is the BDM OUT that supports motorola DBUG12 POD mode.
- J10 is the BDM in interface.
- DB2 has the same pinout as J6 for Dsub 44 pin. The connector is not installed.

Additionally:

- the red LED is controlled by port M bit0, PM0
- the green LED is controlled by port M bit1, PM1
- Resistor POT, R4 provides the voltage to the LCD that is used to adjust the LCD contrast
- RS1, reset switch

6.0 Board Layout




MC9S12A256B
U1
MAX232CWE
U2
SCI0
SCI1
J1
J2
J3
J4
J5
J6
J7
J8
J9
J10
A/D
SHARED IO/LCD/SPI
BDM IN
BDM OUT
DB2
LVI1
S80840
RESET
VR1
LM2937
CR1
VM08
PJ1
C7 100uF
C6 0.1uF
C9 0.1uF
C8 100uF
BYPASS CAPACITORS
D1
1N4148
Y1
16Mhz
L1
L2
10uH
HC05
LD1
LD2
RS1
TITLE
NMIN-12A256B
APPROVALS
DATE
DRAWN T.V.N 051303
CHECKED C.N. 052103
FINISH
SIZE D
DRWG # BCN01
REV 02
SCALE
SHEET

8.0 Examples

These examples may be typed in interactively or cut and pasted into the terminal window if you are using MaxForth. Alternatively, they can be translated to the language that you are using to program the microcontroller with.

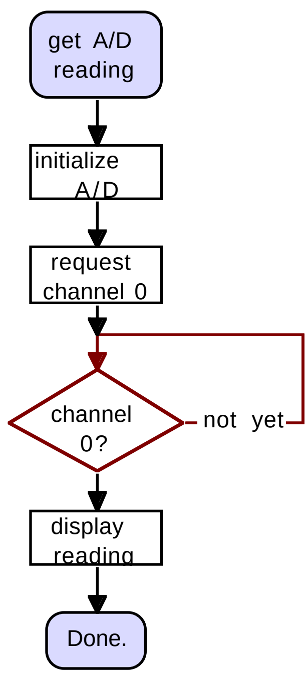
8.1 Playing with the LEDs

There is a green and red LED attached to port M bits 1 and 0 respectively. You can easily turn these on and off from MaxForth using the following code. Note that constants are defined for the registers for convenience:

```
HEX
250 CONSTANT PTM      ( define port M address
252 CONSTANT DDRM     ( define data direction register for port m
1 DDRM C!             ( set bit 0 as an output and all others as inputs
1 PTM C!              ( turn on the red led connected to bit 0
2 DDRM C!             ( set bit 1 as an output and all others as inputs
2 PTM C!              ( turn on the green led connected to bit 1
3 DDRM C!             ( set bits 0 and 1 as outputs; all others as inputs
3 PTM C!              ( turn on both leds
```

8.2 Reading from the A/D port

For this example we will consider the simplest way to get an A/D reading:



This involves: setting up the A/D registers so it is ready to go; requesting a read of a channel; waiting for that channel to complete converting; and finally, reading and displaying the value. Each of these boxes on the diagram will become a word except for Done.

```
HEX
( A/D peripheral registers
82 CONSTANT ATD0CTL2
83 CONSTANT ATD0CTL3
```

```
84 CONSTANT ATD0CTL4
85 CONSTANT ATD0CTL5
86 CONSTANT ATD0STAT
90 CONSTANT ATD0DR0

: INIT-A/D  ( -- )
   7 ATD0CTL4 C!   ( 10 bit resolution; prescaler greater than 6
   40 ATD0CTL3 C!  ( 8 conversions per sequence
   C0 ATD0CTL2 C! ; ( power up, fast flag clear and interrupts off

: REQUEST0  ( -- )
   80 ATD0CTL5 C! ; ( 8 conversions, right unsigned, one-shot, channel 0

: CHANNEL0?  ( -- f )  ATD0STAT C@ 80 AND ;

: DISPLAY-READING  ( -- )  ATD0DR0 @ . ;

: GETAD  INIT-A/D  REQUEST0  BEGIN  CHANNEL0?  UNTIL  DISPLAY-READING ;
```

8.3 Adding a Sensor

The SHT11 from Sensirion is a smart sensor combining temperature and relative humidity sensors with an onboard conversion and a two wire communication facility all in a very tiny package. In the following example it is hooked up to PORT T of the microprocessor. One line is used to provide clock and the other line is used as a bidirectional line for communication.

```
( SHT11 interface for MaxForth  Rob Chapman  Aug 13, 03

( The SHT11 sensor chip provides 14 bit resolution on temperature and
( 12 bit resolution on relative humidity.  The four pins connect to
( +5, GND, PT1 for clock and PT3 for data.
( PT1 is the serial clock; PT3 is the data line and is bidirectional so
( care must be taken not to drive it high, just low so there will be no
( conflicts. It can be driven low but is pulled high by pull up resistor.

HEX
( Registers
242 CONSTANT DDRT   ( data direction register for port T
240 CONSTANT PTT    ( port t outputs
244 CONSTANT PERT   ( port t enable for pull ups

( Debugging
: PT7TRIG  ( pulse pt7 low for debugging with scope
    DDRT C@  80 OR  DUP DDRT C!  ( enable PT5 output
    PTT C@ AND  7F AND  DUP PTT C!  ( set it low
    80 OR PTT C! ;  ( set it high

( Clocks
: K1  2 PTT C@ OR PTT C! ;
: K0  2 NOT PTT C@ AND PTT C! ;
: K01  K0 K1 ;
: K10  K1 K0 ;
: K10S  0 DO K10 LOOP ;

( Data
```

```
: D0 A DDRT C!  PTT C@ 8 NOT AND PTT C! ;
: D1 2 DDRT C! ;

( Protocol: 8 bit command and 16 bit data
: SHT-CMD  ( n -- )  D1 K0  9 K10S K1  D0 K01  D1 K0  D0 3 K10S
   10  5 0 DO  K0  2DUP AND  IF  D1  ELSE  D0  THEN  K1  2/  LOOP  2DROP
   D1 K01 K0 ;
: DAT-READY?  ( -- f )  PTT C@ 8 AND 0= ;
: GET-8  ( n -- n' )  8 0  DO  K0  2*  PTT C@ 8 AND IF  1 OR  THEN  K1 LOOP ;
: GET-DAT  ( -- n )  0 GET-8  K0 D0 K10 D1  GET-8   K01 K0 ;

( Exchanges
: RST  1E SHT-CMD ;

( Initial setup
: INIT-SHT
   2 PLACES     ( for printout format
   2 DDRT C!    ( clock is output always
   FF PERT C! ; ( pull up enabled

DECIMAL

( Tests for temperature in Celsius and relative humidity (RH)
(  Values obtained from chip are in a raw format and need to be massaged
(   Formula for temperature: -40 + .01*rawTE
(   Formula for linear RH: -4 + rawRH*(.0405 + -2.8*10-6 * rawRH )
(   Formula for true RH: linRH + (TE-25)( .01 + .00008*rawRH)

: TEMP  3 SHT-CMD  BEGIN DAT-READY? UNTIL  GET-DAT
   S>F .01E F* 40E F- F.  ;

: RELH  5 SHT-CMD  BEGIN DAT-READY? UNTIL  GET-DAT
   S>F  FDUP -2.8E-6 F*  .0405E F+  FOVER F*  4E F-  ( linear RH
   FSWAP  ( linear rh \ raw rh
   3 SHT-CMD  BEGIN DAT-READY? UNTIL  GET-DAT
   S>F .01E F* 40E F-  ( temperature for compensation
   ( linear rh \ raw rh \ temp
   25E F-  FSWAP  .00008E F* .01E F+  F*  F+  ( RH true )  F. ;
```

To get results from the sensor chip you must first initialize the port and then get data. For example if we get data and then breath on the chip to increase humidity and humidity we can get the following results:

```
INIT-SHT  OK
TEMP 26.36C  OK
RELH 43.94%  OK
( breathe on sensors for 5 seconds
TEMP 27.75C  OK
RELH 80.76%  OK
```

8.4 Implementing an Interrupt

The HCS12 contains a lot of parts to get right (usually all of them) before you can make an interrupt (more generally referred to as an exception) happen. You must set up the CPU, the interrupt controller and an interrupt source such as a peripheral. Setting up the CPU involves modifying CPU control register while setting up the interrupt controller and peripheral involves modifying their memory mapped control registers.

The interrupt machinery on the HCS12 supports a wide range of operational capabilities. You can just use one interrupt or support a complex system of prioritized interrupts from all peripherals. Interrupts can even be forced to happen to provide for a way of testing or syncing.

To set up an interrupt you'd f ollow these steps:

1. write an interrupt service routine which will turn off the source of the interrupt when invoked by the interrupt. This routine must end with the assembly instruction `rti`.
2. put the address of this routine in the right location in the secondary vector table
3. enable the peripheral
4. enable interrupts

8.4.1 Real Time Interrupt Example

The real time interrupt is a simple interrupt to enable and service so it is a good one to start with. This following example is written in assembler and be compiled on a computer and downloaded with the serial loader:

```
; RTI interrupt vector  Rob Chapman  Jun 20, 2003
; startup sets up port M and initializes the real time interrupt (RTI), turns
; on the green LED and then does nothing
; the RTI just changes the red LED every 64ms

; Registers Used
CRGFLG equ $37              ; RTI interrupt flag
RTICTL equ $3B              ; RTI control register
CRGINT equ $38              ; RTI interrupt control
DDRM   equ $252             ; port M data direction register
PTM    equ $250             ; port M outputs: 0 is red, 1 is green

; Startup code
    org $C000
startup:
    lds  #$4000             ; establish a stack
    movb #$03,DDRM          ; drive port M bits 0 and 1
    movb #$02,PTM           ; turn off red LED and turn on green LED
    movb #$7F,RTICTL        ; 64ms timer
    movb #$80,CRGINT        ; enable RTI interrupts
    cli                     ; enable interrupts
lowpower:
    wai                     ; go to low power mode
    bra lowpower            ; save energy

; Service interrupt routine for real time interrupt
sir_rti:
    movb #$80,CRGFLG        ; reset RTI interrupt
    ldaa PTM
    eora #01
    staa PTM                ; toggle red LED
    rti                     ; return from interrupt

; secondary vector table additions
; rti tie in
    org $EFF0   ; RTI vector
    dw sir_rti

; startup tie in
```

```
    org $EFFE   ; application vector
    dw startup
```

To compile this program, you can use the freeware assembler **as12** on a PC or a Mac. The assemblers are with the included files. Once the program is compiled, you must then convert the output srecord with another freeware program **sreccvt**. This gets it into the right download format. Then you download the file and once it is done, press the reset button. You should see the green LED light and the red LED flash rapidly.

NOTE: If you are using the D-Bug12 monitor application, then you will not have to convert the s-record format but you should org to a different address.

On a PC you can assemble and convert from a DOS command prompt and then download with a terminal program. You can either put the **as12** and **sreccvt** programs right in your working directory or put them elsewhere and then add the path to your autoexec.bat file. Once you've established the proper sequence, you can automate it by putting it into a batch file.

On a Mac using OS X, you assemble and convert using a unix terminal window. You can either keep the programs local or put them into a common directory. For instance you could do the following:

```
sudo cp as12 /usr/bin/
Password:
rehash
```

This puts the **as12** program into your `/usr/bin` directory so that you can call it from anywhere. The same procedure can be done for **sreccvt**. The `rehash` command just makes the new command available right away.

To assemble the program:

```
as12 rtiled.s > rtiled.lst
```

This will produce two outputs. The .lst file is a listing of the assembled program while the .s19 file is the output srecord. The srecord file must then be converted to the correct format for downloading:

```
sreccvt -m 00000 fffff 32 -lp rtiled.s19
SRecCvt v1.0.11

Converting S-Record File: rtiled.s19

S-Record File Conversion Complete
```

If you want to see the output, you can view it from the command line:

```
more Out.S19
S2240FC000CF4000180B030252180B020250180B7F003B180B80003810EF3E20FD180B800057
S2240FC02037B6025088017A02500BFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF63
S2240FEFE0FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFC01CFFFFFFFFFFFFFFFFFFFFFFFFC0007D
S9030000FC
```

Download the program by first selecting a to erase the flash and then b followed by the above srecord:

```
D-Bug12 Bootloader v1.0.0

a) Erase Flash
b) Program Flash
c) Set Baud Rate
d) Erase EEPROM
```

```
? a

a) Erase Flash
b) Program Flash
c) Set Baud Rate
d) Erase EEPROM
? b
***
```

Reset the board.

If all goes well, the green LED should be on and the red LED should be blinking. Make sure you change the J4 jumpers for the application to run.

8.4.2 Interrupts Calling Forth

As for calling a Forth word from an interrupt, this is doomed to fail at some point since not all Forth words including the virtual machine are interruptible without some extra context savings. This all adds overhead and goes against keeping interrupts as short as possible. If you keep your interrupts simple and in assembler, then they have a greater chance of working and meeting system time constraints.

8.5 Flash Programming

There is 256K of flash memory available on chip but since the microcontroller has only 16 bits of address space, or 64K, you must access the flash through a programming window.

Flash memory may only be written when it is in the region 0x8000-0xBFFF which is referred to as the program memory page window. This region is a 16K window which can be used to access all of the 256K of flash memory. To change which 16K region of memory is accessed there, you need only change the PPAGE (0x30) register. Since there is only 256K of flash but the register is 8 bits, the memory windows will be unique for a small range only and then wrap after that. For example, putting 0 into PPAGE (HEX 0 30 C!) will access the lowest 16K of the 256K flash memory, but so will 16, 32, 48, etc. To access the top page of flash, which also appears in the memory map from 0xC000 to 0xFFFF, you would store 15, 31, 47, etc. into the PPAGE register (HEX F 30 C!). These sections of flash are referred to as pages of flash. As noted in the memory map (Figure 3 on page 5), page E and page F are permanently in the CPU memory map but they can also be accessed through the programming page window. For instance if you store 14 into the PPAGE register, you will see the same memory image at location 0x4000 as you will see at 0x8000. If you want to install interrupt vectors in the secondary vector table at 0xEF80-0xEFFF, then you must put page F into the programming window. For instance if you want to install an interrupt vector for the real time interrupt (RTI) which is at 0xEFF0, you'd do the f ollowing:

```
HEX
F 30 C!
address_of_interrupt_vector AFF0 FL!
```

Note that 0xAFF0 is 0x4000 less than where the actual interrupt vector is to be but that it will appear there. If you try to use FL! in any other memory area outside of the programming window, it will not work.

As described in the microcontroller manual on flash memory, the upper 16 bytes of EEPROM are reserved as control registers for the EEPROM. You should avoid setting values in this range (0xFF0-0xFFF) unless you know what you are doing. Setting the wrong values in this region has the potential to lock out use of the EEPROM from being erased.

The EEPROM differs from the flash memory in two other aspects. Its erase size is 4 bytes while the flash is 512 bytes. This makes the EEPROM easier to reprogram in small amounts. In MaxForth you can program a byte location irregardless of its value as it will be erased first by EEC! if necessary. In flash memory, the minimum programming size is an aligned 2 bytes and the location must be 0xFFFF to begin with. To program EEPROM use EEC!, EE!, EEMOVE and EEWORD. To program flash, use FL!, FLMOVE, FLERASE and FLWORD. EDP is used by EEWORD and FDP is used by FLWORD.