MotionC-P™

C/C++ Programmable, Standalone, DSP 4-axis Servo or Stepper Motion Controller
with Opto-couplers, Solid State Relays, ADC, DAC, and high voltage I/Os

Technical Manual

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Chapter 1: Introduction

1.1 Functional Description

The MotionC-P is a C/C++ programmable Standalone 4-axis motion controller with 80+ I/Os, Optos and SSRs

Features:

- 4.55 x 5.3", 200 mA at 12V, –40° to 80°C
- C/C++ programmable, with remote debugger IDE, and samples
- Driven by **AE, AE86, i386-Engine, i386E-M, or 586-Engine™**
- **MCP2540:** 4 axis stepping open-loop control with pulse, direction
- Stall detection with 4 quadrature encoder inputs
- **MCP2140/2120:** 4 or 2-axis closed-loop servo control
- 7 solenoid drivers, 40+ TTL I/Os, 2 RS232, 1 RS485
- 32 Opto-couplers for home, limit,capture, and fault switches
- 16 opto isolated Solid State Relays (SSR) for AC or DC loads
- 32-bit registers for position, velocity, acceleration, and jerk
- S-curve, trapezoidal, velocity-contour, and electronic gearing
- 5 MHz pulse rate, 100 μs programmable loop rate, and 8 ADCs

The ***MotionC-P™(MCP)*** is a low-cost, high-performance, standalone, C/C++ programmable industrial controller for up to 4-axis motion control. The ***MCP*** supports a DSP chipset (**MC2140/2120/2540/2520**, PMD) with build in sophisticated field proven control firmware. The MCP must be driven by a host C/C++ programmable TERN controller. User only needs to define parameters for PID algorithm and trajectory profile. The DSP calculates velocity, position and stabilizes the motor output, while the host controller interfacing with user PC, monitoring I/Os, reads ADCs, computing or pre-loading a new set of parameters.

The host controller interfaces to the DSP chipset via high-speed data bus. User can easy develop application C/C++ program on a PC, download, and debug via serial link. The host writes pre-defined motion commands to the DSP, and the DSP can interrupt the host at any time.

The ***MCP*** provides a total of 32 opto-couplers for home switches, limit switches, fault switches and other user inputs. Seven solenoid drivers are capable of sinking up to 350 mA at 50 V. Eight opto-isolated Solid State Relays (SSR) can switch 100 mA AC or DC loads upto 230V. Two PPI (82C55) chips provide 48 I/O lines. Two RS-232 and one RS-485 drivers can be installed. Additional I/Os, memory, ADC, and DAC can be provided by the host **AE**/**IE/586E**.

MCP2140 supports up to 4-axis closed-loop digital servo control for a variety of servo motors. It uses incremental quadrature encoders for position feedback and it supports high speed DACs for ±8V servo control voltage output. Each axis contains sophisticated trajectory profile and digital servo capabilities, allowing very low position and velocity tracking errors. The 4-axis operation can be programmed either independently or in synchrony to allow advanced multi-axis motion such as circular and continuous-path profiles. It provides electronic gearing, PID/PI control, a choice of S-curve, trapezoidal, or contoured velocity profile modes, 1/T counter for stable low-velocity motion, automatic motor error shutdown, monitoring travel limit switches, home switches, capture switches, and fault switches. **MCP2120** is a 2-axis servo version.

MCP2540 is for 4-axis open-loop stepping motor control. It supports sophisticated trajectory generation and synchronization features, allowing the creation of complex motion sequences. It provides up to 3 MHz pulse and direction signals for driving step motor systems. **MCP2520** is a 2-axis stepper version.

Seven solenoid drivers are capable of sinking up to 350mA at 50V. Two PPIs (82C55), each provides 24 user-programmable bi-directional I/O lines. Two RS-232 and one RS-485 drivers can be installed.

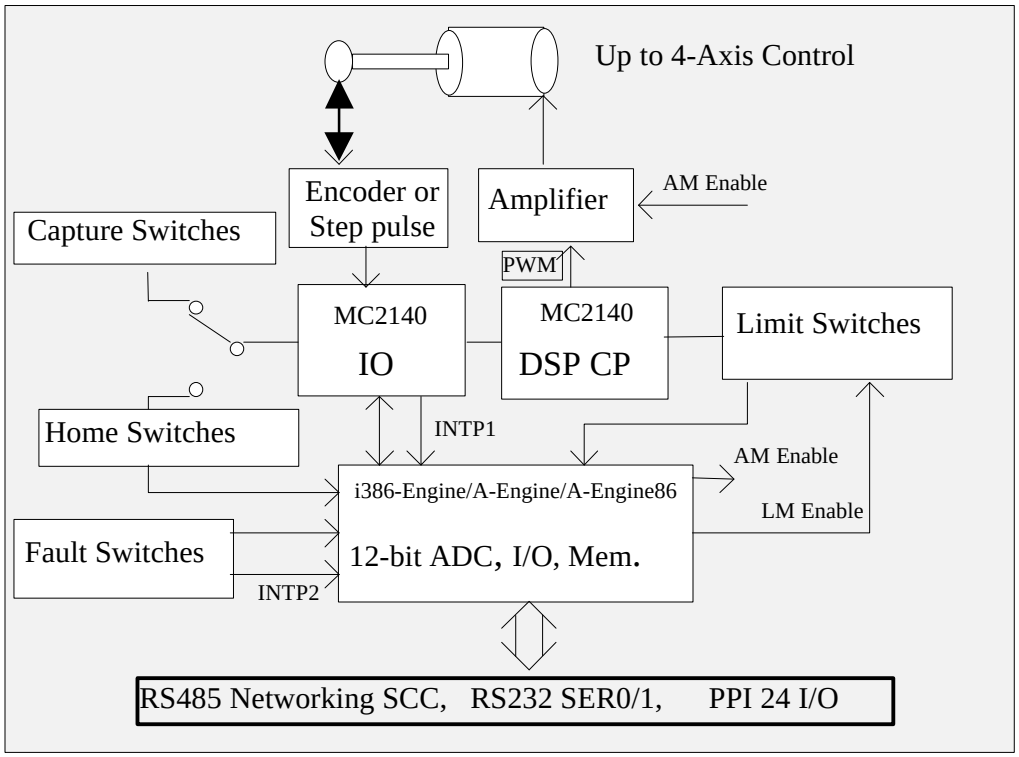


Figure 1.1 Funcitonal block diagram of the *MCP*2140

1.2 Physical Description

The physical layout of the *MotionC-P* is shown in Figure 1.2.

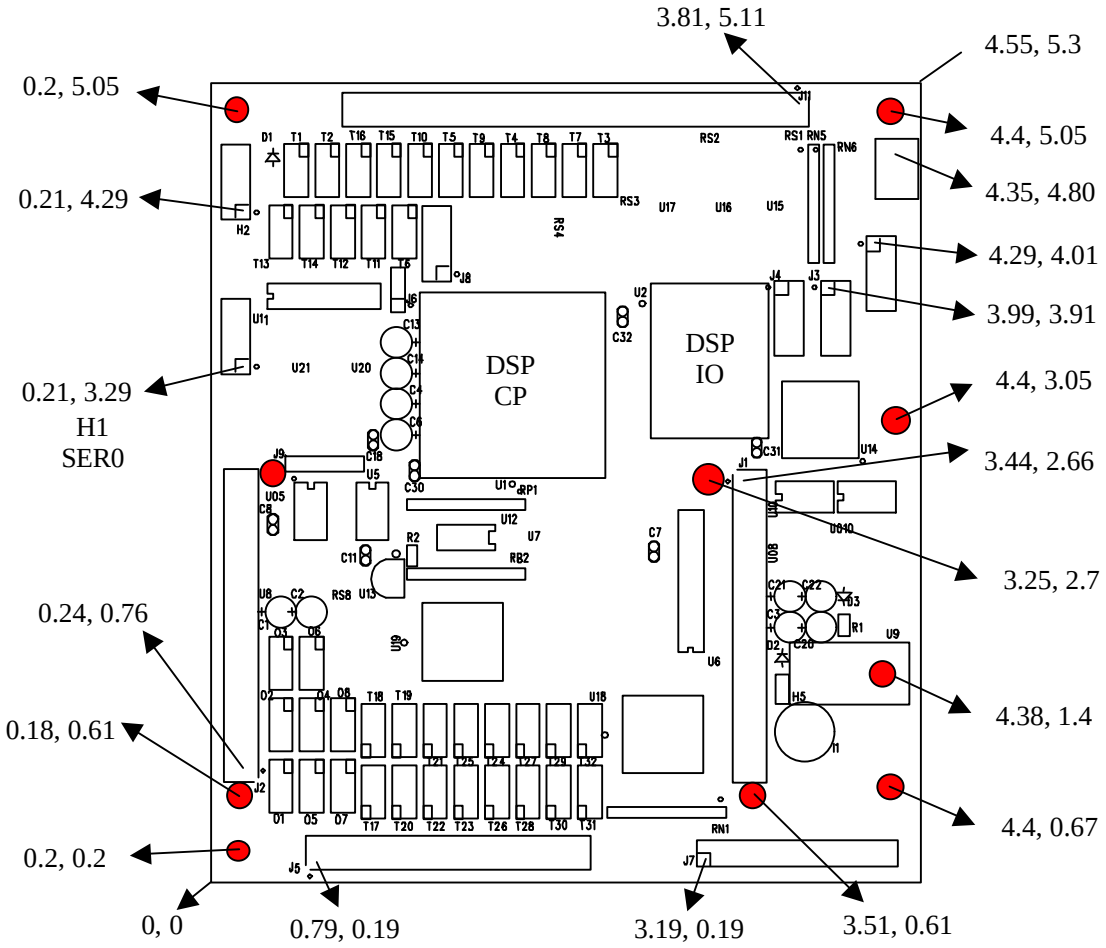
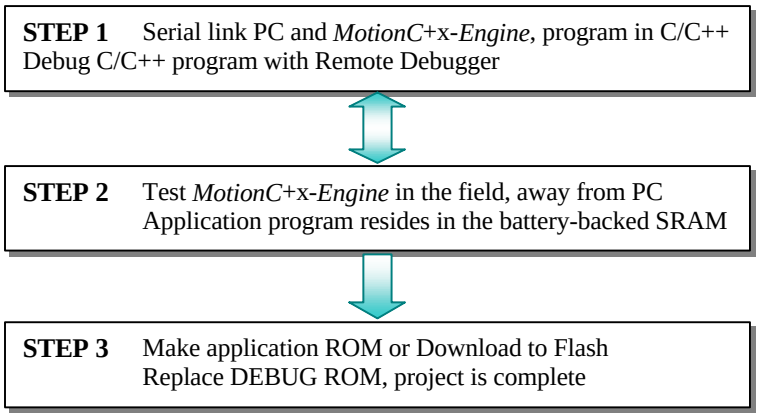


Figure 1.2 Physical layout of the *MotionC-P*

1.3 *MotionC*2140 Programming Overview

Development of application software for the *MotionC*-P consists of three easy steps, as shown in the block diagram below.



There are three possible steps in the development of a C/C++ application program. These steps are explained thoroughly in the Technical Manuals for the *A-Engine/A-Engine86/i386-Engine/586-Engine*. Please refer to the Tutorial section in the Technical Manuals for the *EV-P and DV-P* Kit to obtain further details on programming the *MotionCP*+x-*Engine*.

- The *MotionC-P*+x-*Engine* is programmed using your PC via RS-232 serial link. Your C/C++ program can be remotely debugged over the serial link at a rate of up to 115,000 baud.

1.3.1 Minimum Hardware Requirements

- PC or PC-compatible computer with serial COMx port that supports 115,200 baud
- *MotionC-P*
- x-*Engine* controller with DEBUG ROM
- PC-V25 serial cable (RS-232; DB9 connector for PC COM port and IDE 2x5 connector for controller)
- Center negative wall transformer (+9V 500 mA)

1.3.2 Minimum Software Requirements

TERN EV-P or DV-P Kit
PC software environment: Windows 95, 98, NT, 2000

Chapter 2: Installation

2.1 Software Installation

Please refer to the Technical manual for the "C/C++ EV-P or DV-P Kit for TERN controllers".

2.2 Hardware Installation

Hardware installation for the *MotionC-P* consists primarily of connecting the microcontroller to your PC.

Overview

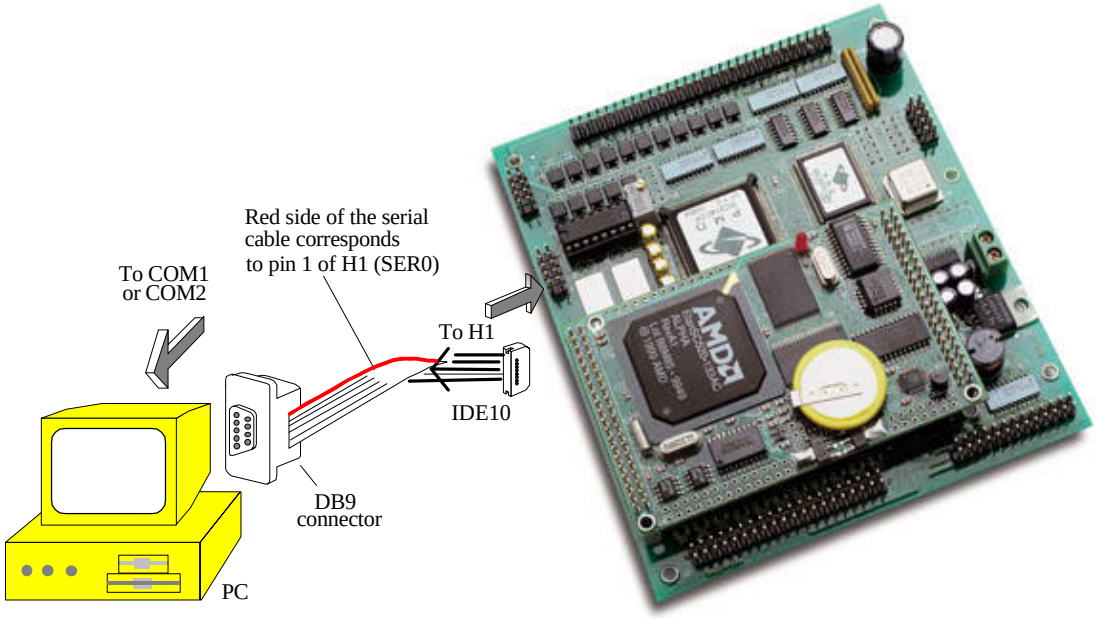
- Install x-*Engine* controller to the *MotionC-P*
- Connect PC to the *MotionC-P* using a RS232 cable.
- Connect 9V wall transformer to DC power jack on *MotionC-P*
- User is ready to begin development

2.2.1 Connecting the MotionC-P to a 586-Engine/ i386-Engine/A-Engine/A-Engine86

Install the x-*Engine* controller on the MC-P via J1 (20x2) and J2 (20x2) header.

The *MotionC-P* is linked to the PC via a serial RS232 cable (PC-V25).

IMPORTANT: *The **red** side of the cable must point to pin 1 of SER0 header.* The DB9 connector should connect to one of your PC's COM Ports (COM1 or COM2).



Chapter 3: Hardware

3.1 *586-Engine, i386-Engine,* i386-Engine-M*, A-Engine or A-Engine86*

The *MotionC*-P must be driven by a 586-Engine, or *i386-Engine*, or *A-Engine* or *A-Engine86,* as the host C/C++ programmable controller. Please refer to the corresponding x-*Engine* Technical Manual for more information.

3.2 Interface with PMD MC2x40 DSP chipset

The *MotionC*-P supports PMD's DSP Motion control chip sets, including MC2140/2340/2440/2540/2840. The *MC*2x40 DSP chipset is packaged in two surface mount chips, "CP" and "I/O". The chipset is driven by a host x-*Engine* via an 8-bit, bi-directional port. Communication to and from the chipset consist of packet-oriented messages. An interrupt line /HINT, from the "CP" pin 98, is routed to J2 pin 6 of the *i386-Engine* (/INT6), *A-Engine* (/INT1), or *A-Engine86,* so the chipset can signal the host when special conditions occur, such as receiving an encoder index pulse.

The *i386-Engine*/*A-Engine/A-Engine86* writes commands to the *MC*2x40 and reads data from the *MC*2x40 chipset. Each command consists of a 16-bit word, with a command code value defined in the *MC*2x40 manual. Data is transmitted to and from the chipset in 16-bit words.
"C" Functions are available in **mc21.lib** and prototypes are listed in mc21.h file. Many sample programs are also included in the CD of the *EV-P or DV-P* kits.

void mc21_host_dat_wr(unsigned int dat); // host Engine writes 16-bit dat to MC
void mc21_host_cmd_wr(unsigned char cmd); // host Engine writes 16-bit cmd to MC
unsigned int mc21_host_dat_rd(void); // host Engine reads 16-bit dat from MC
char mc21_host_rdy(void); //return 0 for "I/O" pin 8, HRDY low, indicating busy

3.3 *MotionC* 2x40 I/O Map

The following tables list the I/O address of the *MC*2x40, together with their Data Bits, Chip-Select Symbol and Functions.

Base I/O Address	Data Bits	Select Symbol	Function
0xD0	D0-D7	/MC	Read/Write D0-7 from/to *MC*2x40 "I/O" chip (U2)
0xB0	D0-D7	/PPI	Read/Write D0-7 from/to PPI 82c55 I/O chip (U18)
0xA0	D0-D7	/PP	Read/Write D0-7 from/to PPI 82c55 I/O chip (U19)
0xC0	D0	/RST1	Hardware reset "CP".

3.4 Quadrature Encoder Inputs (*MC*2x40)

The *MC*2x40 supports up to 4 channels of Incremental Encoder inputs for motor position information. Each quadrature encoder channel consists of a square wave, offset 90-degree from the other. For every channel, four position inputs and control signals are supported:

A channel pulse (QDAx); B channel pulse (QDBx); Index pulse, and Home switch signal.

Differential line drivers (75173) are used to support differential quadrature inputs. The quadrature encoder inputs are not optically isolated from digital ground (GND).

3.5 *MCP*2140 DAC Servo Analog Outputs

*MCP*2140 uses a 60-pin motion interface connector J11.

The *MCP*2140 supports both DAC and PWM output mode for external servo motor amplifier. The *MCP*2140 uses a quad 12-bit voltage output DAC converter (DAC7625). While the 16-bit DAC output mode is used, the 12-bit DAC uses the higher order 12 bits date from the CP chip.

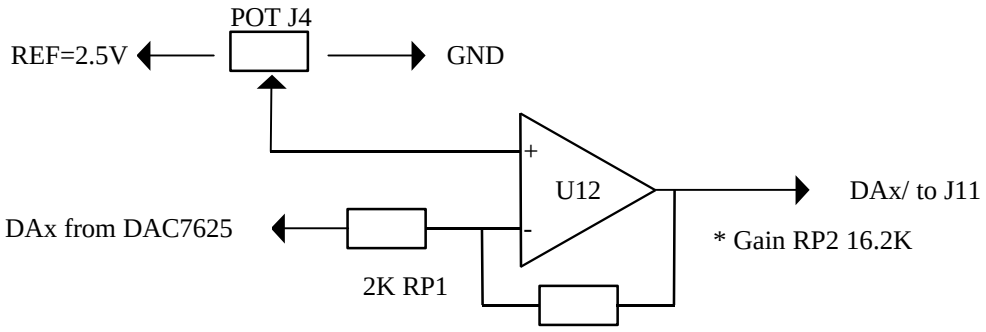
The DAC7625 contains four precision output buffer amplifiers, providing full 12-bit performance at 1LSB total unadjusted error without adjustments. The DAC7625 has a typical 3µs output setting time and outputs 0 to 2.5V with an external 2.5V precision reference. A quad amplifier buffer with adjustable gain and offset supports 4 channels of default ±10V analog servo control signals at header J11 (DA1-4), supporting a variety of motor amplifier interfaces.

A resistor pot is installed in J4 providing the offset voltage. User may replace default 16K gain resistors in RP2 to setup necessary gains.

The DA1/(J11p45), DA2/(J11p46), DA3/(J11p31), and DA4/(J11p32) provides buffered output voltage from the operational amplifier (U12), capable up to 20 mA. The *MC*2140 outputs a 16-bit data word as an unsigned 16-bit number with a range of 0-65535.

Output Value	Output (Volts)
0	DAC outputs 0 volt
32768	DAC outputs 1.25 volts
65536	DAC outputs 2.5 volts

The DA1/(J11p45), DA2/(J11p46), DA3/(J11p31) and DA4/(J11p32) are adjusted buffered output voltages. The default output voltages are -10V for an output value of -32768, 0V for an output value of 0, and +10V for an output value of +32768. The 10K pot installed in J4 is used to adjust the reset analog voltage output to zero. See sample program ***mc21_dac.c*** for detail.



3.6 Limit, Home, and Fault Switches

There are 2 limit switch inputs for each axis: +L1 and –L1. There are a total of 8 limit switch inputs (+L1-4, and –L1-4). There are also 4 home switch inputs: HOM1-4 and 4 fault switch inputs: FLT1-4. All switch inputs are routed to J11 and protected by opto-couplers. All switch inputs are high by default, and can be high actived with ground signal. See sample programs: **mc21_h_i.c**, and **mc25_sta.c** for details.

3.7 Power Amplifier Control, Solenoids, and Solid-State-Realys

There are 7 lines of high voltage drivers (U11, ULN2003) designed to sink up to 350 mA at 50V. Four drivers routed to the J11 header (EN1-4), are driven by the "CP" output pins (O1-O4, pin 94-97). These drivers are designed for power amplifier enable control in a digital servo system. Three drivers (HV1-3) are routed to H1 SER0 header. HV1-3 are driven by the host *x-Engine* via J2 header pin 11, 18, and 20. Please refer to the MCP schematic and sample program "mcp_hvo.c" for more details.
Eight SSRs can be installed on the MCP. These SSRs (PS2701, NEC) has a zero ohm contact (upto 10 mA) while enabled, and Open contacts while disabled.

3.8 Power Supplies, Digital and Analog Ground

The *MCP* can be powered by a single 12V DC (with on-board 5V regulator) or 24V DC (with a on-board switching regulator), via J11(30x2 header) or screw terminal (J0). The on-board linear 5V or optional switching regulator (U9) can produce 5V for the DSP and the host engine. The RS232 drivers (U8 and U08) are powered by 5V and produces negative voltage for both RS-232 and operational amplifiers. Use a 12V wall transformer, as default.

User may provide regulated field power supply +12V, -12V, VCC and GND via J11 header. OEM product may use external 5V power supply with the on-board 5V regulator removed.

If you use the on-board +5V VCC regulator (7805) to power the external quadrature encoders, you will need to provide additional large heat sinks to the 7805 regulator, such as mounting on a large metal standoff. If you want to provide an external regulated +5V to the *MotionC*2140 via J11, you should not install the on-board 5V regulator.

3.9 24x2 I/O Lines of Two PPI

There are 24 bi-directional user programmable I/O lines (G00-G07, G10-G17, G20-G27) at J7 header. These 24 TTL level I/O pins are provided by U18 (uPD71055, or 85C55) can be used to interface to with LCDs, Keypads, or power relay drivers.

Eight PPI lines of U19 should be programmed to support 8 outputs (B20-B27) for the 8 Solid-State-Relays (SSR). The remaine 16 PPI pins are programmed as inputs, and protected by 16 opto-couplers.

See sample program **mcp_ppi.c** for details.

3.10 RS-232 and RS-485 drivers

Two channels of RS-232 serial port drives are available on the *MotionCP*2x40.

- H1 SER0 for debugging
- H2 SER1 for application.

An RS-485 driver and header H3 supports the optional SCC2691 UART.

3.11 Protected Opto-coupler Inputs

Quadrature decoder inputs, QA1-4, QB1-4, and ID1-4 are protected by differential line drivers (75173). All home switches (HOM1-3), Limit switches (+L1-4, -L1-4), and Fault switches (FLT1-4), are protected by opto-couplers. All inputs can take up to 30V DC input.

3.12 DSP Ready Signal to the Host *i386-Engine/A-Engine/A-Engine86*

The DSP IO chip pin 8 (HRDY) is a hardware ready signal that indicates the DSP is busy while it is low.

The *MCP* routes HRDY signal to:

- *i386-Engine* - J2 pin 12 (P14)
- *A-Engine* – J2 pin 12 (P10)

Chapter 4: Software

Please refer to the Technical Manual for the "C/C++ Development Kit for TERN 16-bit Embedded Microcontrollers" on debugging and programming tools. For software information related to the *A-Engine, A-Engine86, or i386-Engine* controller, please refer to the respective manual.

4.1 Functions in MC21.LIB

void ***mc21_host_dat_wr***(unsigned int dat); // host A-Engine writes 16-bit dat to MC21

void ***mc21_host_cmd_wr***(unsigned int cmd); // host A-Engine writes 16-bit cmd to MC21

unsigned int ***mc21_host_dat_rd***(void); // host A-Engine reads 16-bit dat from MC21

char ***mc21_host_rdy***(void); // return 0 for MC IO pin 8 low, indicating host port busy

```
unsigned int mc21_host_status_rd(void); // return 16 bits of the
status register of DSP chipset.

void mc21_hard_reset(void); // Issue a hardware reset to the DSP chipset

unsigned int mc21_adc_rd(char ch); // reads 10-bit ADC from DSP
      // ch=0-7 for AN1-8 at header J8
```

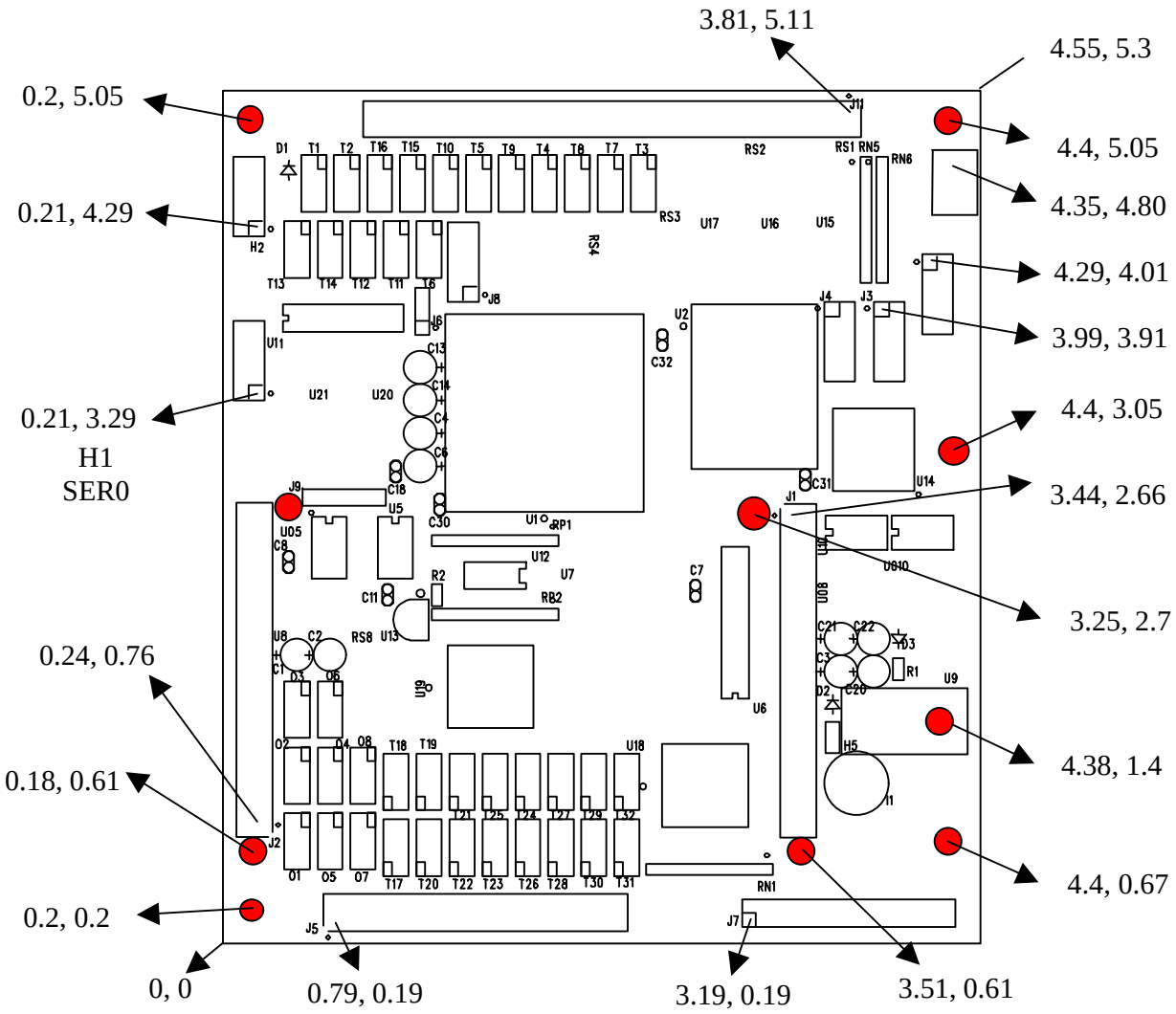
4.2 Sample Programs

Sample programs for the *MotionC-P* are located in the samples directory at

C:\TERN\x86\samples\mc21,

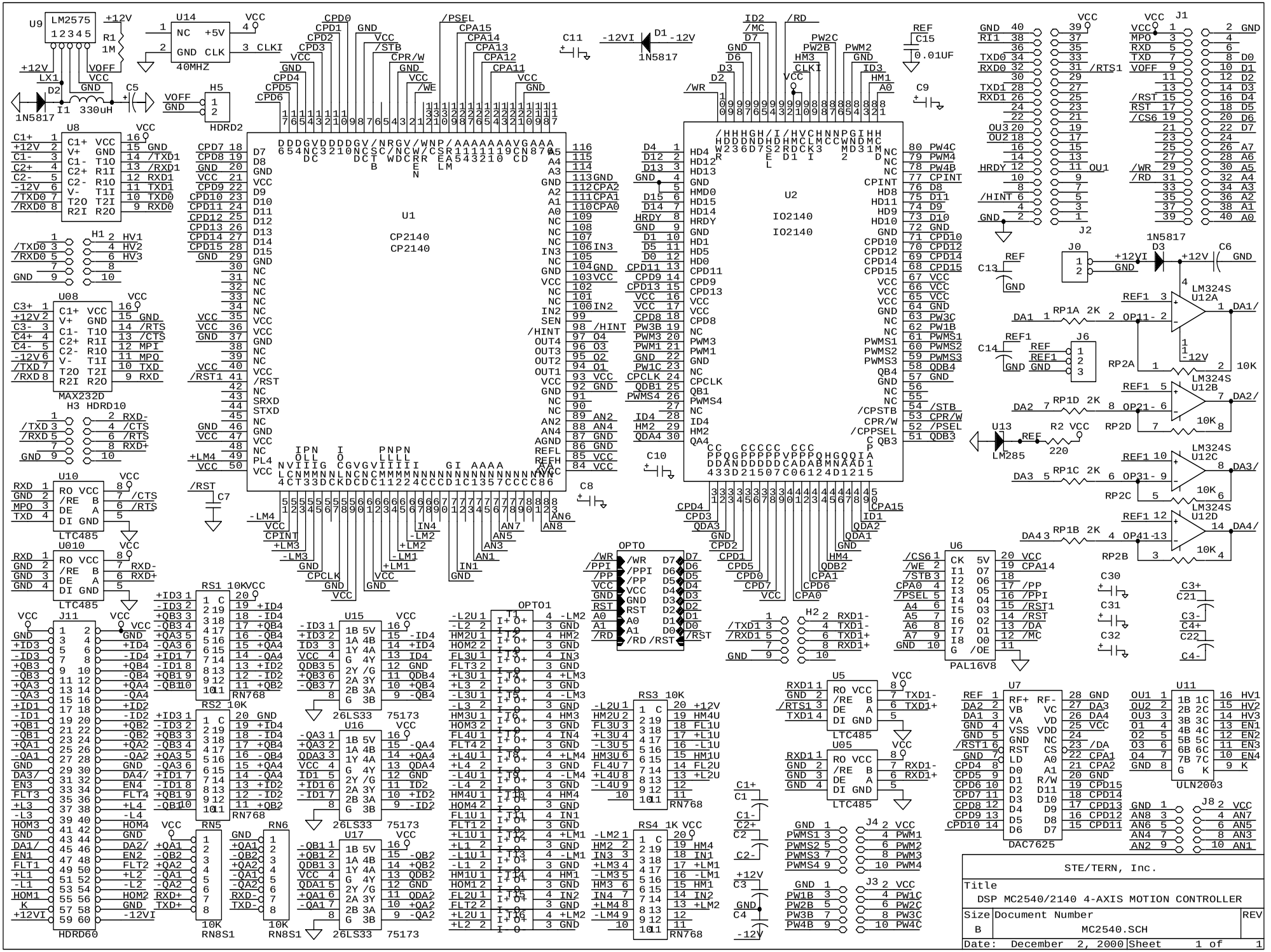
C:\TERN\x86\samples\mcp

Mc21_pwm.c
Mc21_ppi.c
Mc21_adc.c
Mc21_dac.c
Mc21_sta.c
Mc21_f_int.c
Mc21_h_int.c
Mc21_d3.c
Mc21_pos.c
MC21_ver.c
Mc25_pos.c
Mcp_sta.c
Mcp_ppi.c
Mcp_hvo.c
Mcp_h_i.c



A Total of 10 Mounting Holes, marked in RED.

MC-P Layout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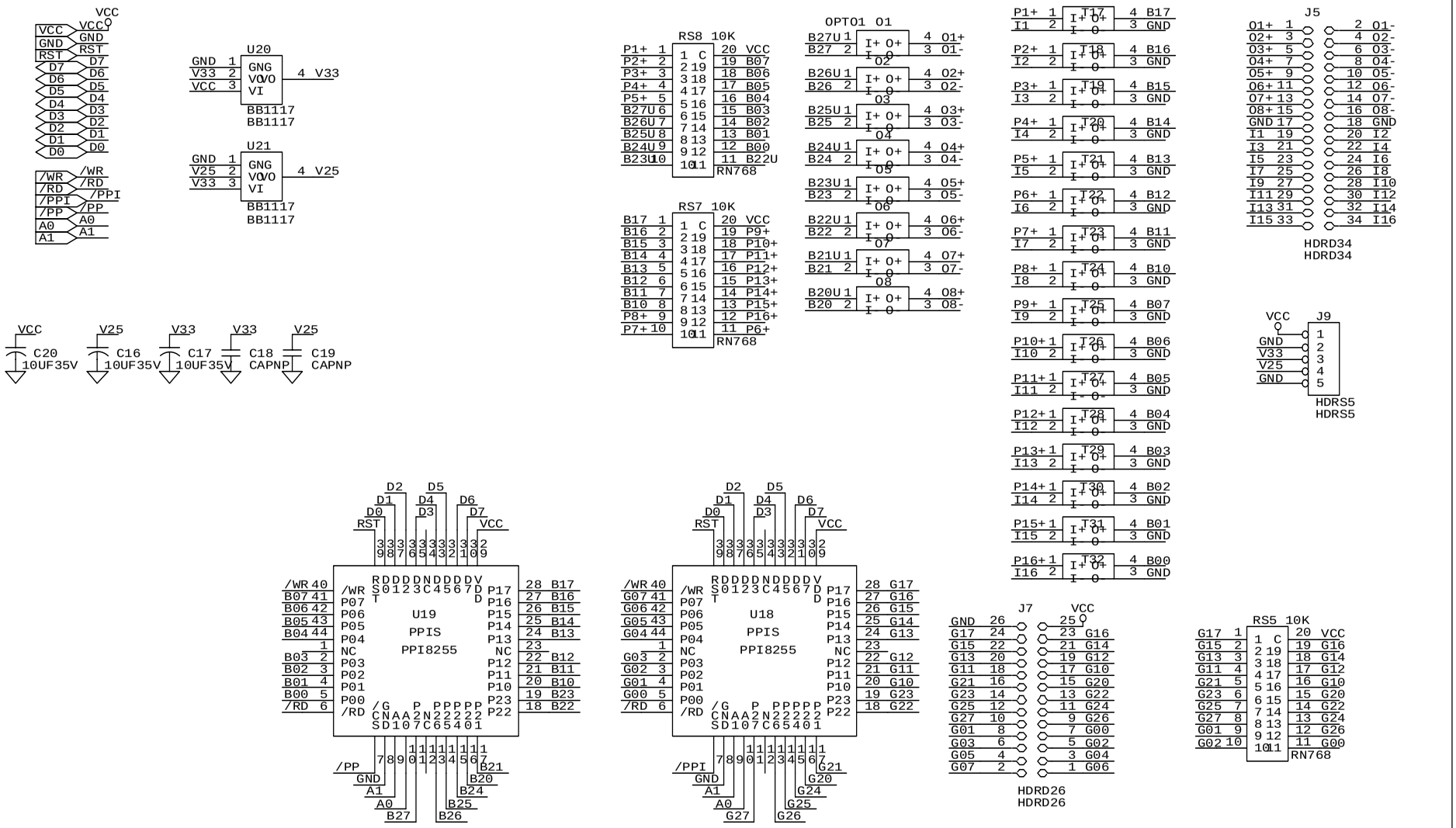
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RST
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D6
D5
D4
D3
D2
D1
D0
/WR
/RD
/PPI
/PP
A0
A1
U20
GND 1
V33 2
VCC 3
GNG
VO/O
VI
4 V33
BB1117
U21
GND 1
V25 2
V33 3
4 V25
RS8 10K
RS7 10K
RN768
OPTO1 O1
B27U 1
B27 2
B26U 1
B26 2
B25U 1
B25 2
B24U 1
B24 2
B23U 1
B23 2
B22U 1
B22 2
B21U 1
B21 2
B20U 1
B20 2
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I- O-
O1
O2
O3
O4
O5
O6
O7
O8
P1+ 1
I1 2
P2+ 1
I2 2
P3+ 1
I3 2
P4+ 1
I4 2
P5+ 1
I5 2
P6+ 1
I6 2
P7+ 1
I7 2
P8+ 1
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P9+ 1
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4 B13
4 B12
4 B11
4 B10
4 B07
4 B06
4 B05
4 B04
4 B03
4 B02
4 B01
4 B00
J5
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HDRD34
J9
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HDRS5
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C16 10UF35V
C17 10UF35V
C18 CAPNP
C19 CAPNP
U19
U18
PPIS
PPI8255
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P07 T D P16
P06 P15
P05 P14
P04 P13
NC NC
P03 P12
P02 P11
P01 P10
P00 P23
/RD CNAA2N22222 P22
SD107C65401
D2 D5 D1 D4 D6 D0 D3 D7 RST VCC
3 3 3 3 3 3 3 3 3 3 2
9 8 7 6 5 4 3 2 1 0 9
/WR 40
B07 41
B06 42
B05 43
B04 44
1
B03 2
B02 3
B01 4
B00 5
/RD 6
28 B17
27 B16
26 B15
25 B14
24 B13
23
22 B12
21 B11
20 B10
19 B23
18 B22
/PP
GND
A1
A0
B27
B26
B21
B20
B24
B25
G07 41
G06 42
G05 43
G04 44
G03 2
G02 3
G01 4
G00 5
28 G17
27 G16
26 G15
25 G14
24 G13
22 G12
21 G11
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19 G23
18 G22
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G21
G20
G24
G25
G27
G26
J7
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Sheet 1 of 1