AN1624

ITC137 68HC708MP16 Motion Control Development Board

By Jim Gray, Bill Lucas, and Warren Schultz

Introduction

A controller that complements software development tools for the 68HC708MP16 is presented here. It provides motor control functions on a board that interfaces easily with power stages and emulators. Its configuration is applicable to ac induction, brush dc, and brushless dc motors.

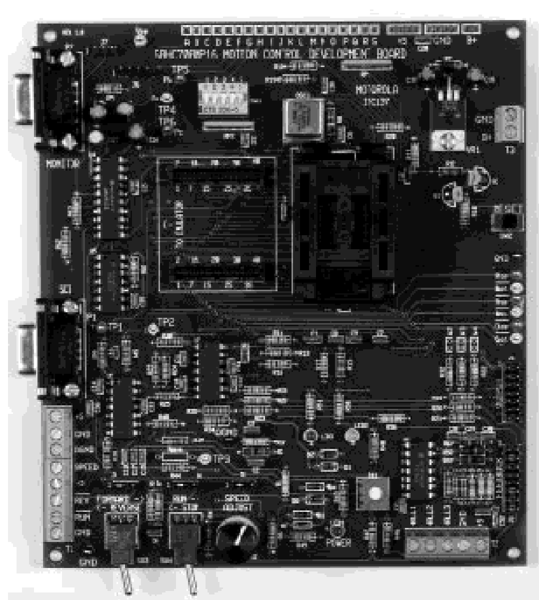

Figure 1. ITC137 Development Board

Description

A summary of the information required to use motion control development board number ITC137 is presented as follows. Discussions of hardware design and software are included under separate headings.

Function

The systems development board shown in **Figure 1** is designed to provide control signals for 3-phase ac induction, brush dc, and 3-phase brushless dc motors. With the software supplied, it is set up to run ac induction motors.

Inputs are accepted from switches and a potentiometer on the board or external RUN/STOP, FORWARD/REVERSE, and SPEED signals. The speed input is a 0- to +5-volt signal with 0 volts corresponding to 0 speed, and 5 volts producing full speed. RUN/STOP and FORWARD/REVERSE are logic inputs, with logic lows producing run and reverse outputs. Hall 1, Hall 2, and Hall 3 inputs are also provided for connection to brushless dc motors.

The ITC137 motion control development board is designed to run in two configurations. It will operate on its own with the processor supplied. With the processor removed, it will connect to an M68HC08MP16 emulator via an M68CBL08A cable. For purposes of motion control code development, the emulator may be run on either an MMDS08 or MMEVS08.

The output side of this board connects to an ITC122 or ITC132 power stage via ribbon cable. Six outputs provide power device control signals for 3-phase induction or brushless dc motors. Brush dc motors can be controlled by using either one or two of the three available phases. All six outputs will sink 20 mA, making them suitable for directly driving opto couplers in isolated gate drives. A switched +5 volts is also provided to serve as the B+ power source for opto coupler input diodes. It is turned off at reset to facilitate orderly power-up and power-down of the gate drives.

Electrical Characteristics

The electrical characteristics in **Table 1** apply to operation at 25 degrees Celsius and unless otherwise specified B+ = 12 volts.

Table 1. Electrical Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Power supply voltage Driving ITC122 Driving ITC32	B+	 7.5 7.5	 — —	 28 15	 Volts Volts
Power supply voltage	+5	4.75	—	5.25	Volts
Minimum logic 1 input voltage	V_{IH}	—	2.7	—	Volts
Maximum logic 0 input voltage	V_{IL}	—	2.0	—	Volts
Quiescent current	I_{CC}	—	80	—	mA
SPEED input	V_{SPEED}	—	20	—	%/volt
Buffer gain V_{Temp} V_{Bus} I_{Sense}	 $A_{V\ (VTemp)}$ $A_{V\ (VBus)}$ $A_{V\ (ISense)}$	 — — —	 –16.9 2 2	 — — —	 — — —
Output sink current	—	—	—	25	mA

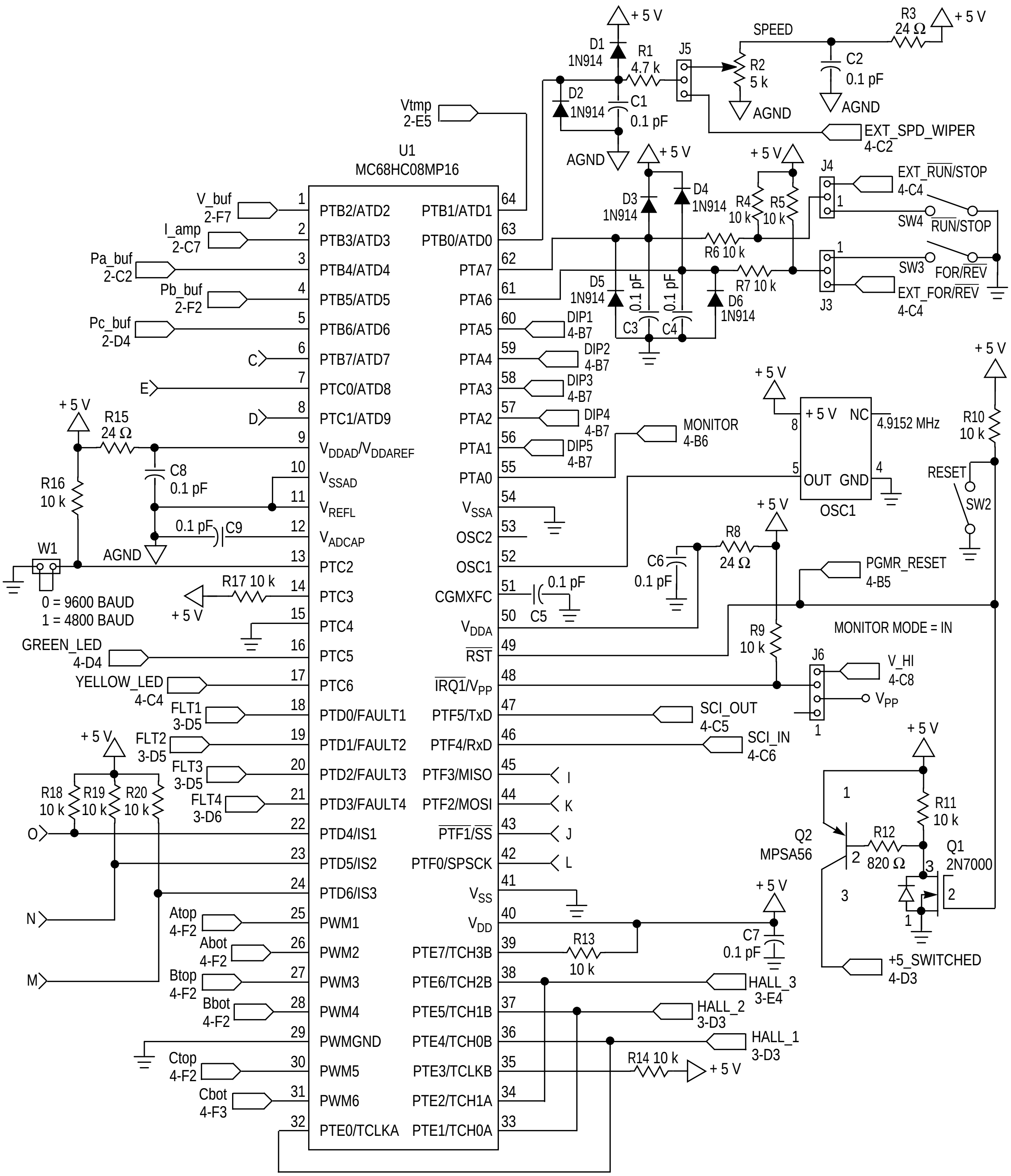

Figure 2. Schematic

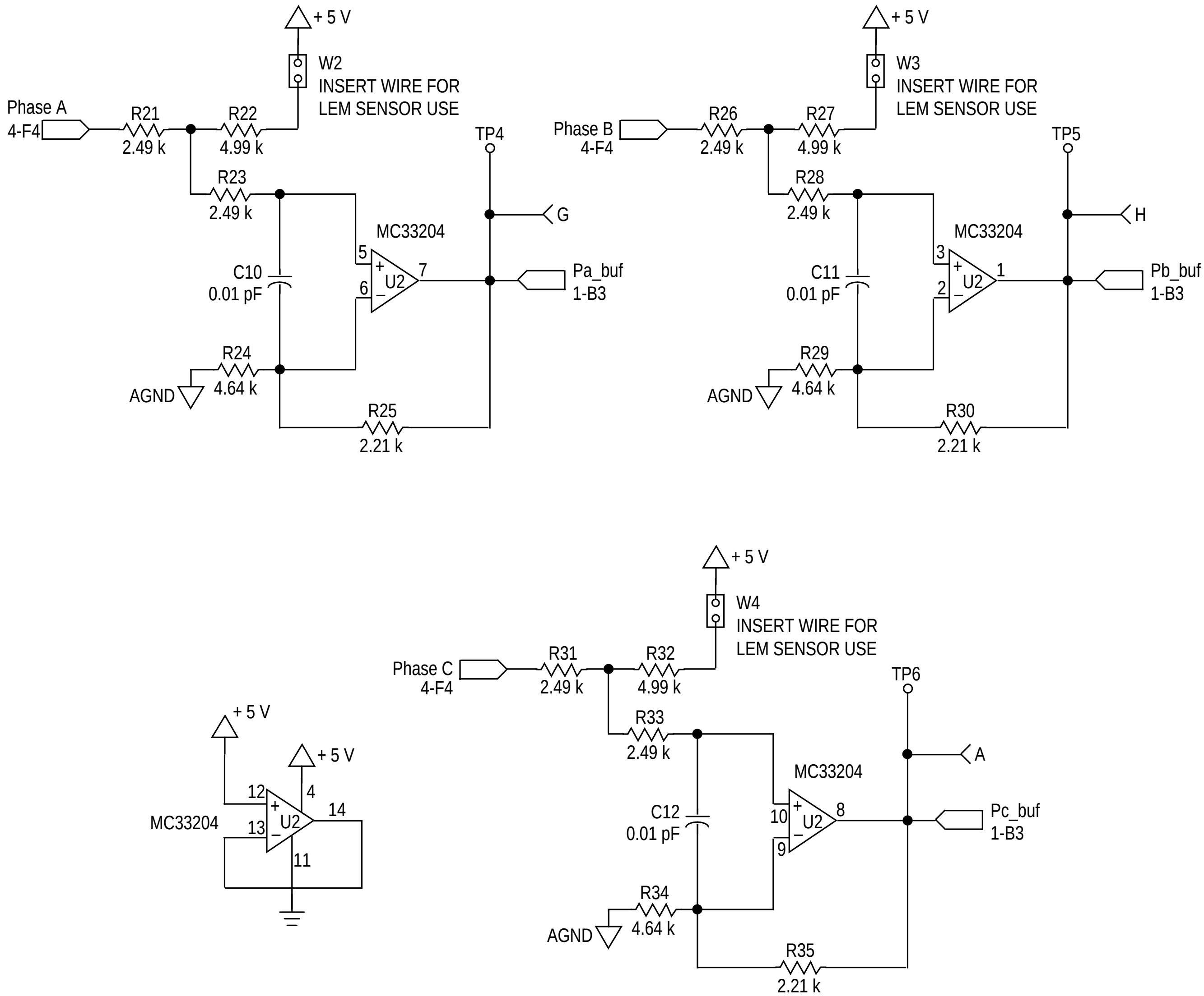

Figure 3. Schematic (Sheet 1 of 2)

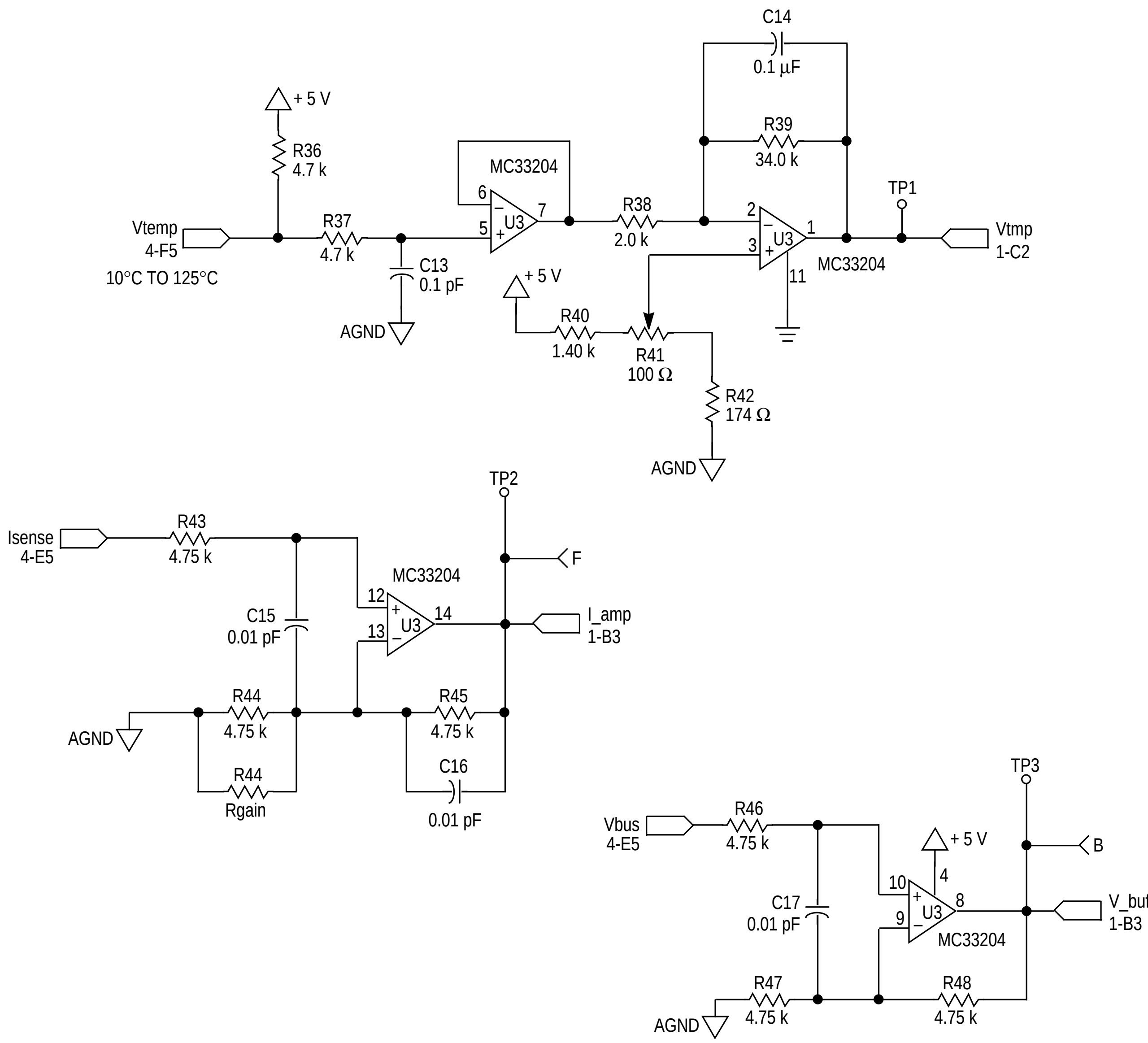

Figure 3. Schematic (Sheet 2 of 2)

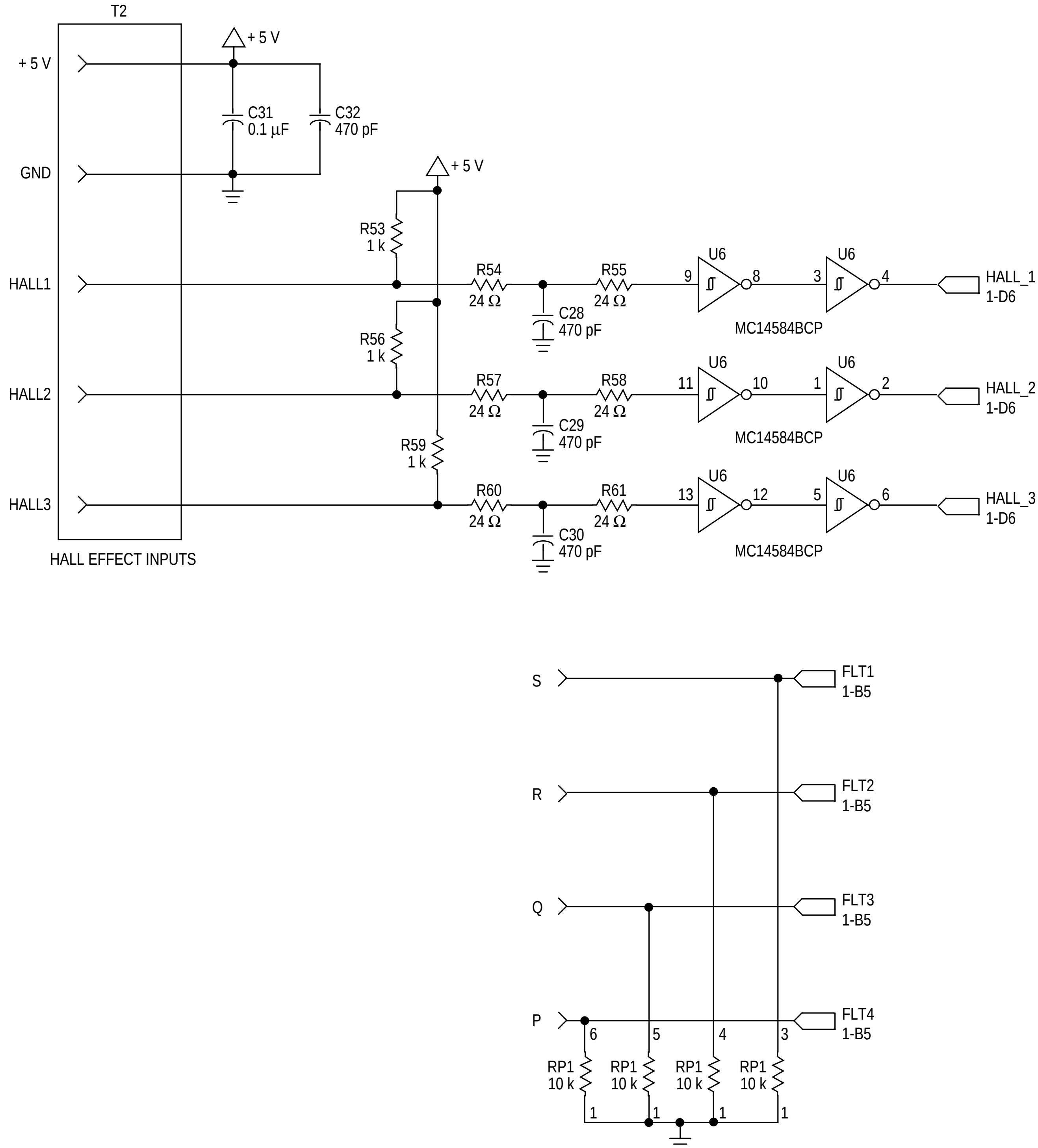

Figure 4. Schematic

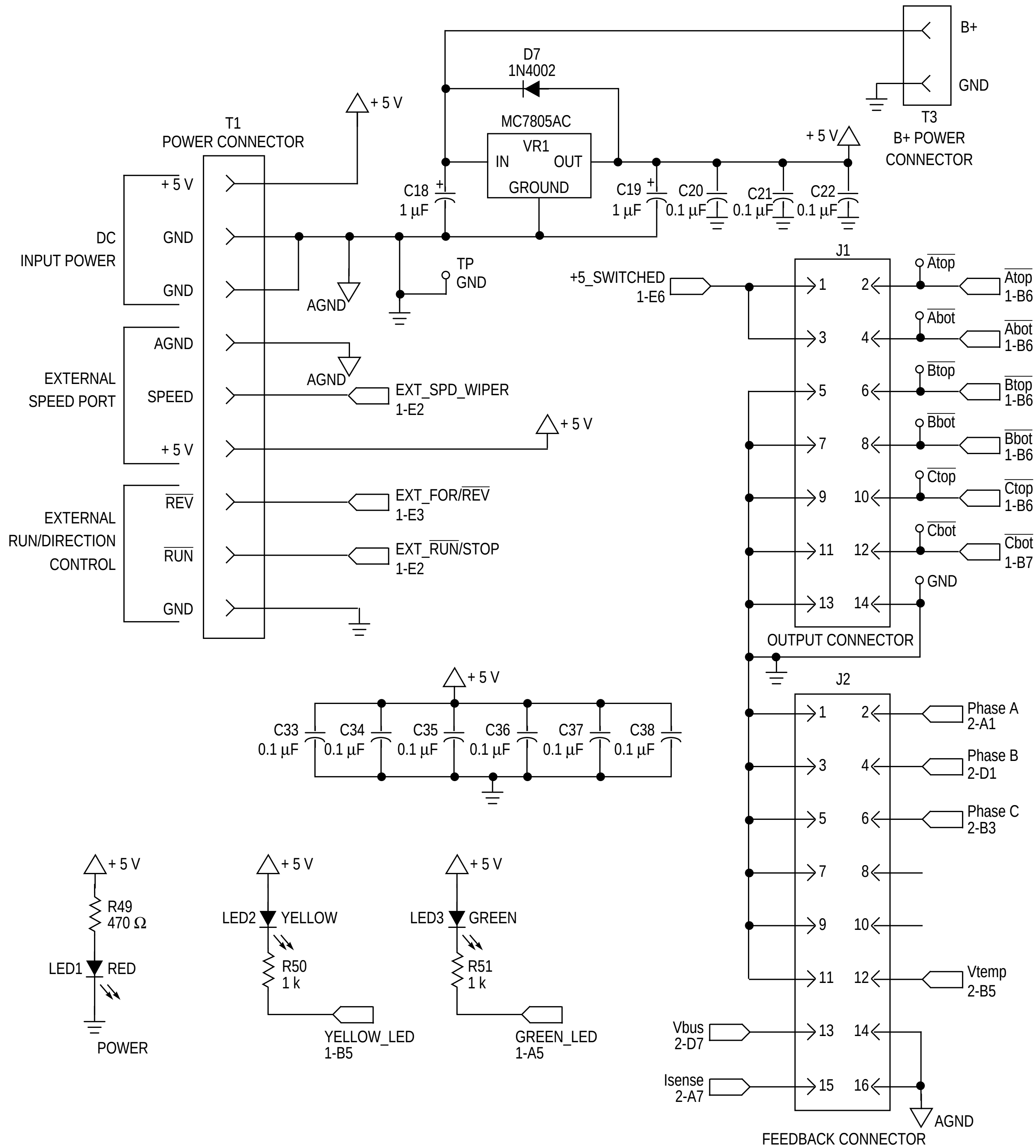

Figure 5. Schematic (Sheet 1 of 2)

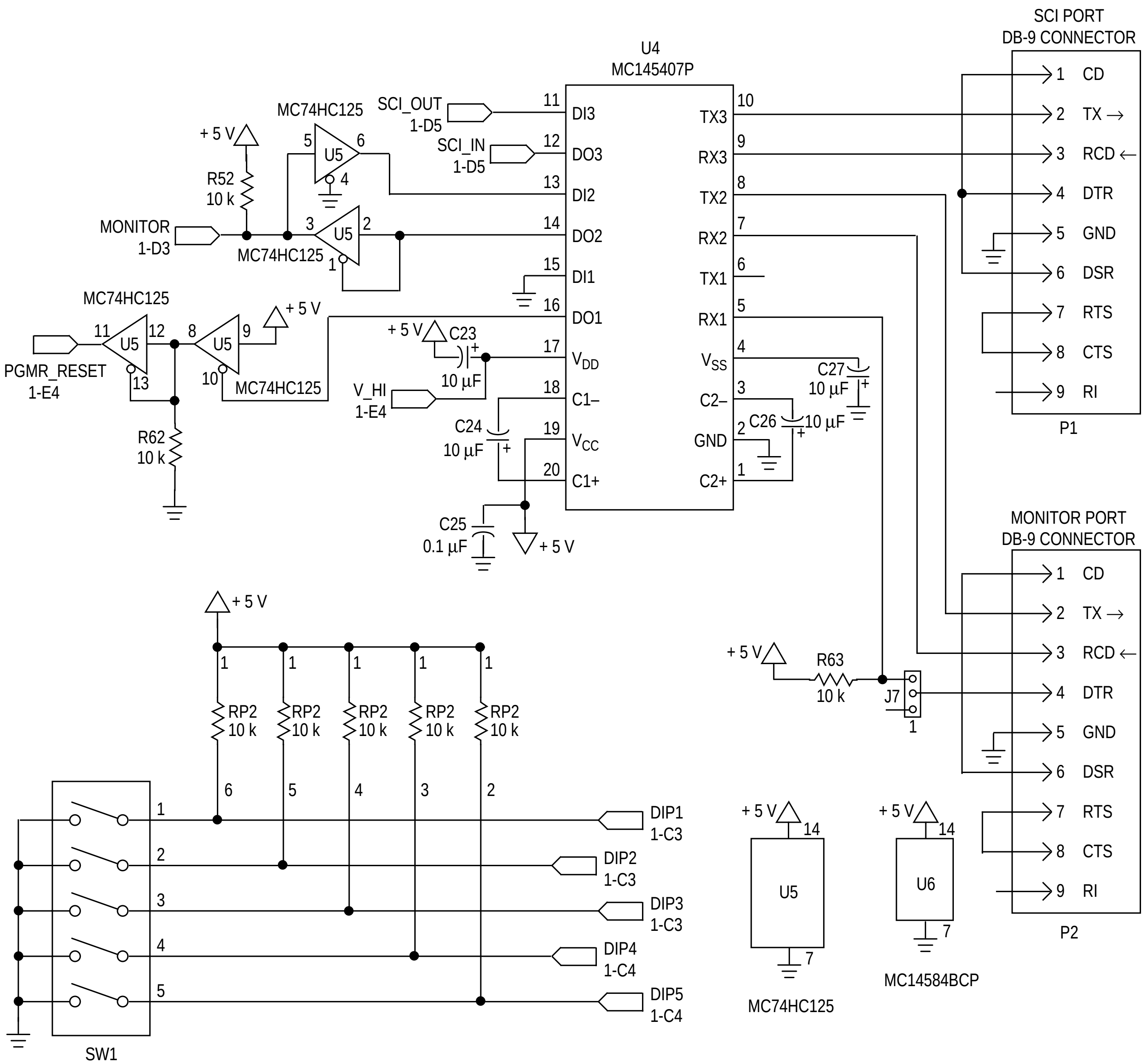

Figure 5. Schematic (Sheet 2 of 2)

Table 2. Parts List

Designators	Quantity	Description	Manufacturer	Part Number
C1–C9, C13, C14, C20–C22, C25, C31, C33–C38	22	0.1-µf capacitor	Sprague	1C105Z5U104M050B
C10–C12, C15–C17	6	.01-µf capacitor	Sprague	1C105Z5U103M050B
C18, C19	2	1-µF electrolytic capacitor	Mepco-Centralab	CN15A220K
C23, C24, C26, C27	4	10-µF electrolytic capacitor	Digi-Key Corp.	P5272
C28-C30, C32	4	470-pF capacitor	Sprague	1C105Z5U471M050B
D1–D6	6	Small signal diode	—	1N914
D7	1	General-purpose diode	Freescale	1N4002
J1	1	2 x 7.1o.c jumper block note 2	Digi-Key Corp.	S2011-36-ND
J2	1	2x8 .1o.c. jumper block note 2	Digi-Key Corp.	S2011-36-ND
J3, J4, J5, J7	4	1x3 .1o.c. jumper block note 3	Digi-Key Corp.	S1011-36-ND
J6	1	1x4 .1o.c. jumper block note 3	Digi-Key Corp.	S1011-36-ND
LED1	1	Red LED	General Instruments	MV5774C
LED2	1	Yellow LED	General Instruments	MV5374C
LED3	1	Green LED	General Instruments	MV5474C
P1, P2	2	DB-9 connector (female)	Digi-Key Corp.	A2100-ND
Q1	1	Small signal FET transistor	Freescale	2N7000
Q2	1	Small signal PNP transistor	Freescale	MPSA56
RP1, RP2	2	10 kΩ, 6-pin, SIP resistor pack	Digi-Key Corp.	770-61R10K-ND
R2	1	5-kΩ variable resistor	Clarostat Sensors and Controls, Inc.	392JB-5k-S
R4–R7, R9, R10, R11, R13, R14	—	—	—	—

Table 2. Parts List (Continued)

Designators	Quantity	Description	Manufacturer	Part Number
R16–R20, R52, R62, R63	17	10-kΩ resistor	Yageo Corp.	—
R12	1	820 kΩ resistor	Yageo Corp.	—
R21, R23, R26, R28, R31, R33	6	2.49-kΩ resistor 1%	Yageo Corp.	—
R22, R27, R32	3	4.99-kΩ resistor 1%	Yageo Corp.	—
R24, R29, R34	3	4.64-kΩ resistor 1%	Yageo Corp.	—
R25, R30, R35	3	2.21-kΩ resistor 1%	Yageo Corp.	—
R1, R36, R37	3	4.7-kΩ resistor	Yageo Corp.	—
R38	1	2.00-kΩ resistor 1%	Yageo Corp.	—
R39	1	34.0-kΩ resistor 1%	Yageo Corp.	—
R40	1	1.40-kΩ resistor 1%	Yageo Corp.	—
R41	1	100-Ω trim potentiometer	Digi-Key Corp.	3386P-101-ND
R42	1	174-Ω resistor 1%	Yageo Corp.	—
R43–R48	6	4.75-kΩ resistor 1%	Yageo Corp.	—
R49	1	470-Ω resistor	Yageo Corp.	—
R50, R51, R53, R56, R59	5	1-kΩ resistor	Yageo Corp.	—
R3, R8, R15, R54, R55	—	—	—	—
R57, R58, R60, R61	9	24-Ω resistor	Yageo Corp.	
SW1	1	5 POS DIP switch	CTS	CT2068-ND
SW2	1	SPST push-button switch	NKK	AB15AP-FA
SW3, SW4	2	SPST toggle switch	NKK	A12AH
T1	1	8-screw terminal connector	Phoenix Contact	MKDSN 1, 5/8–5,08
T2	1	5-screw terminal connector	Phoenix contact	MKDSN 1,5/5–5,08
T3	1	2-screw terminal connector	Phoenix contact	MKDSN 1,5/2–5,08
U1, socketed	1	Microprocessor	Freescale	MC68HC708MP16

Table 2. Parts List (Continued)

Designators	Quantity	Description	Manufacturer	Part Number
U1X, U1 socket	1	QFP 64-pin socket	Prine Distributors	FPQ-64-0.8–10A
U2, U3	1	Quad op-amp	Freescale	MC33204P
U4	1	RS-232 driver/receiver	Freescale	MC145407P
U5	1	Quad bus driver	Freescale	MC74HC125P
U6	1	Hex Schmitt trigger	Freescale	MC14584BCP
VR1	1	Voltage regulator	Freescale	MC7805ACT
OSC1	1	4.9152-MHz oscillator	Digi-Key Corp./CTS	CTS156-ND
GND, GND, AGND	3	Test point black	Components Corp.	TP-104-01-00
Atop, Btop, Ctop, TP1, TP5, TP6	6	Test point red	Components Corp.	TP-104-01-02
Abot, Bbot, Cbot, TP2, TP3, TP4, V_{PP}	7	Test point yellow	Components Corp.	TP-104-01-04
No designator	1	4-40 x 1/4-inch screw for VR1	—	—
No designator	1	4-40 nuts for VR1	—	—
No designator	5	Shorting jumpers for J3–J7	Digi-Key Corp.	929955-06-ND
No designator	6	Self-stick rubber feet	—	—
ITC137	1	PC board	—	—

Pin-by-Pin Description

Inputs and outputs are grouped into six connectors.

Control signal inputs are located on screw connector T1. They are optional external interfaces that include a provision to power the board with +5 volts if the B+ input on connector T3 is not used. Screw connector T2 contains three Hall sensor inputs, a +5-volt connection for the Hall sensors, and a ground. B+, if used instead of the +5-volt input, is supplied through screw connector T3. It will accept power supply voltages from 7.5 to 28 volts when driving an ITC122 power stage, and 7.5 to 15 volts when driving an ITC132. The lower voltage limit for driving the ITC132 comes from the need to supply more current from the 5-volt bus to drive opto-coupled inputs.

Ribbon connector J1 contains six outputs for driving a power stage and a switched 5-volt power line. Feedback signal inputs are located on ribbon connector J2, where there is provision for temperature, bus voltage, and current sense feedback signals.

There is also a DB-9 connector for RS-232 serial port communications and a DB-9 connector for monitor mode. Ribbon connector pinouts are shown in **Figure 6**.

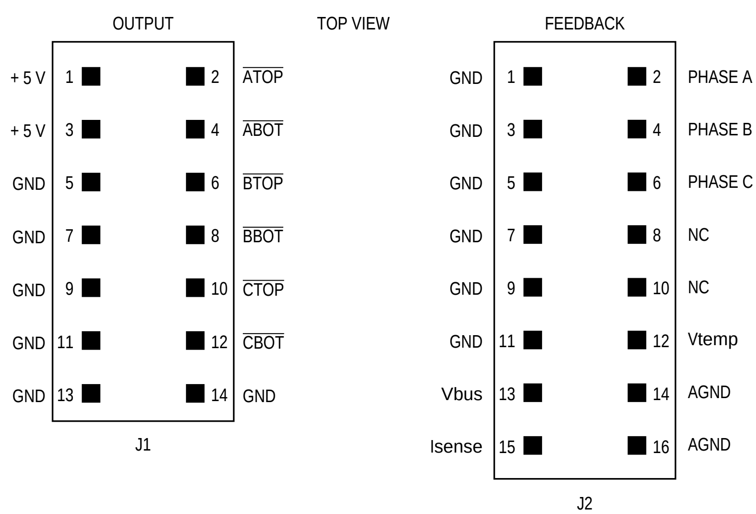

Figure 6. Connector Pinouts

B+ Connector T3

B+ B+ is one of two possible power supply connections. The board either requires a power supply on this input or a +5-volt supply on connector T1, not both. For operation with an ITC122 power stage, the B+ input voltage range is 7.5 to 28 volts dc. For operation with an ITC132 power stage, it is 7.5 to 15 volts dc.

GND The GND terminal on this connector is intended as the return for power supply B+.

Input Connector

+5 This input is an alternate input to B+. If it is used, no connection to B+ is required.

GND There are multiple ground connections. The one adjacent to +5 is intended as the +5-volt return.

AGND An analog ground for the speed control input is labeled AGND.

SPEED This input can be used to control motor speed with an external 0- to 5-volt analog signal. Zero volts corresponds to 0 speed and 5 volts to full speed. To use it, jumper J5 needs to be moved to the external position, which disables the on-board speed control potentiometer. As shipped, J5 is set to control speed from the potentiometer.

$\overline{REV}$ This is an external logic input that reverses the motor when it is grounded. To use it, jumper J3 needs to be moved to the external position, which disables the on-board FORWARD/REVERSE switch. As shipped, J3 is set to control direction from the switch.

$\overline{RUN}$ This is an external logic input that enables the motor when it is grounded. To use it, jumper J4 needs to be moved to the external position, which disables the on-board RUN/STOP switch. As shipped, J4 is set to control run/stop from the switch.

Hall Connector T2

HALL 1, HALL 2, HALL 3 — These inputs are intended to receive open collector Hall sensor outputs from brushless dc motors. They are buffered with Schmitt triggers and filtered for noise immunity.

+5 — This connection is for +5 volts that the board supplies to Hall sensors in a brushless dc motor.

GND — GND on this connector is the Hall sensor ground.

Feedback Connector J2

I_{Sense} — Pin 15 of feedback connector J2 is a current sense input. It is connected to A/D channel ATD3 through a gain of 2 non-inverting amplifier.

V_{Bus} — Pin 13 of connector J2 is a motor bus voltage input. It is connected to A/D channel ATD2 through a gain of 2 non-inverting amplifier.

V_{Temp} — Pin 12 on connector J2 is a temperature sense input. It is connected to an amplifier that is designed to translate the forward voltage of a diode into a usable A/D voltage. The output of this amplifier is connected to A/D channel ATD1.

AGND — Pins 14 and 16 are tied to AGND, which is a ground for analog circuits. This ground is routed such that all of the analog returns connect with digital ground at just one point.

Phase Voltage Feedback — Phase feedback signals phase A, phase B, and phase C are also included on feedback connector J2. They are located on pins 2, 4, and 6. When used with an ITC122 power stage, a divided down phase voltage appears at these pins. With an ITC132 power stage, no signals appear at these pins unless they are supplied by the user.

Output Connector J1

Switched +5 Pins 1 and 3 are connected to the 5-volt bus through a switch that is open at reset. The resulting switched 5 volts can be used to power input diodes in opto-coupled gate drives, such as the ones found in ITC132 power stages. Its use facilitates orderly power-up and power-down of the gate drives.

GND Pins 5, 7, 9, 11, 13, and 14 are tied to ground. They provide a return for the switched +5 and are used to provide noise isolation between output lines in a ribbon cable.

$\overline{Atop}$ —$\overline{Cbot}$ Outputs are located on pins 2, 4, 6, 8, 10, and 12. They provide control signals for three phases of half-bridge configured output transistors and are set up in an active low configuration. They have the current sinking capability to drive opto-coupled power stages such as an ITC132.

SCI Port DB-9 Connector

This DB-9 connector is set up for RS-232 communication with personal computers. It has standard RS-232 pinouts. When connected to a serial port on a personal computer, it can be used to allow keyboard control of motor drive functions.

Monitor Mode DB-9 Connector

The monitor mode DB-9 connector is included to support background debug for the HC708MP16.

Test Points

TP1–TP3 Test points TP1, TP2, and TP3 provide access to buffered feedback signals for temperature, motor bus current, and motor bus voltage. These voltages are seen by A/D converter inputs ATD1, ATD3, and ATD2. The temperature feedback voltage can be calibrated with potentiometer R18.

TP4–TP6 Test points TP4, TP5, and TP6 provide access to buffered feedback signals from feedback connector J2 pins 2, 4, and 6.

GND and AGND These test points are provided to facilitate grounding test instruments.

Outputs All six outputs and a ground are also available as test points. They are connected in parallel with the outputs on ribbon connector J1.

Switches

SW1 SW1 (switch 1) is a 5-position DIP switch that enables modulation parameters to be changed while a motor is running. Switch positions are illustrated in **Figure 7**. Position 1 sets full modulation for either 60 or 120 Hz. Position 2 selects either sine wave or third harmonic pulse-width modulation (PWM). Positions 3, 4, and 5 select PWM frequency per **Table 3** in the software section of this application note.

SW2 SW2 (switch 2) is a push-button switch located on the right-hand edge of the board. It is labeled RESET. It resets the processor and turns off the switched 5 volts supplied on output connector J1.

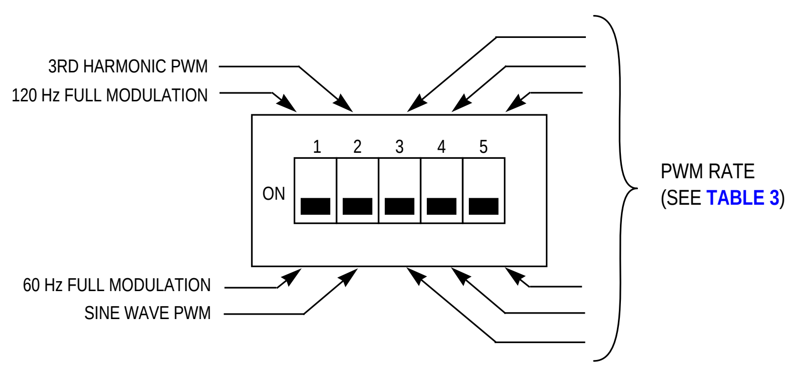

Figure 7. Switch 1

Potentiometers

R2 R2, labeled SPEED ADJUST, is the speed control potentiometer. It controls motor speed unless jumper J5 is set to the external position or control is taken over by the SCI port.

R41 R41 is a small potentiometer that is used for adjusting the analog signal that represents temperature. Setting the voltage at test point TP1 to 1 volt at 25 degrees Celsius with this potentiometer is the recommended default calibration.

Expanded I/O

There are a number of blank pads located at the top of the printed circuit board. They are included to allow a user to expand the capability of the system with a prototype board. The connections are described from left to right.

A Pad A is connected to the output of a non-inverting amplifier that has its input at feedback connector J2 pin 6. This amplifier has a gain of 1.5. Its output also connects to the processor's analog input ATD6.

B Pad B provides access to the bus voltage feedback signal. It is connected to the output of a non-inverting amplifier that has a gain of 2 and its input at feedback connector J2 pin 13. This signal also ties to the processor's analog input ATD2.

C Pad C is connected to the processor's analog ATD7 input pin.

D Pad D is connected to the processor's analog ATD9 input pin.

E Pad E is connected to the processor's analog ATD8 input pin.

F Pad F provides access to the bus current feedback signal. It is connected to the output of a non-inverting amplifier that has a gain of two and its input at feedback connector J2 pin15. This signal also ties to the processor's analog input ATD3.

G Pad G is connected to the output of a non-inverting amplifier that has its input at feedback connector J2 pin 2. This amplifier has a gain of 1.5. Its output also connects to the processor's analog input ATD4.

H Pad H is connected to the output of a non-inverting amplifier that has its input at feedback connector J2 pin 4. This amplifier has a gain of 1.5. Its output also connects to the processor's analog input ATD5.

I Pad I is connected to the processor's MISO pin.

J Pad J is connected to the processor's $\overline{SS}$ output pin.

K Pad K is connected to the processor's MOSI pin.

L Pad L is connected to the processor's SPSCK output pin.

M Pad M is connected to the processor's IS3 input pin. This signal is pulled up to +5 volts through a 10-kΩ resistor.

N Pad N is connected to the processor's IS2 input pin. This signal is pulled up to +5 volts through a 10-kΩ resistor.

O Pad O is connected to the processor's IS1 input pin. This signal is pulled up to +5 volts through a 10-kΩ resistor.

P Pad P is connected to the processor's FAULT4 input pin. This signal is pulled to logic ground through a 10-kΩ resistor.

Q Pad Q is connected to the processor FAULT3 input pin. This signal is pulled to logic ground through a 10-kΩ resistor.

R Pad R is connected to the processor's FAULT2 input pin. This signal is pulled to logic ground through a 10-kΩ resistor.

S Pad S is connected to the processor's FAULT1 input pin. This signal is pulled to logic ground through a 10-kΩ resistor.

+5 Four pads labeled +5 provide +5 volts from the on-board 7805 regulator for prototype circuitry.

GND Four pads labeled GND provide logic ground for use by additional prototype circuitry.

B+ Two pads labeled B+ are connected to the B+ power input on terminal 3.

Application Example

An application example, shown in **Figure 8**, illustrates system connections to an ITC132 power stage and an induction motor. This arrangement can run stand alone or the ITC137 can be connected to an MMDS08 for code development. The two boards are designed such that the drive and feedback ribbon connectors line up. Ribbon cables are supplied. Once they are plugged in, it is only a matter of connecting power supplies and the motor to get a system up and running.

A 3-phase, center-aligned, sine wave pulse-width modulation (PWM) signal is generated by the ITC137. Speed is controlled by the frequency and amplitude of this signal, while direction is determined by phase-to-phase sequence. Systems parameters are easily changed, while a motor is running. Switch 1 on the ITC137 board will change PWM rate, modulation type, and full modulation frequency. If the RS-232 communications interface is used, terminal mode operation includes inputs for boost voltage and several types of space vector modulation.

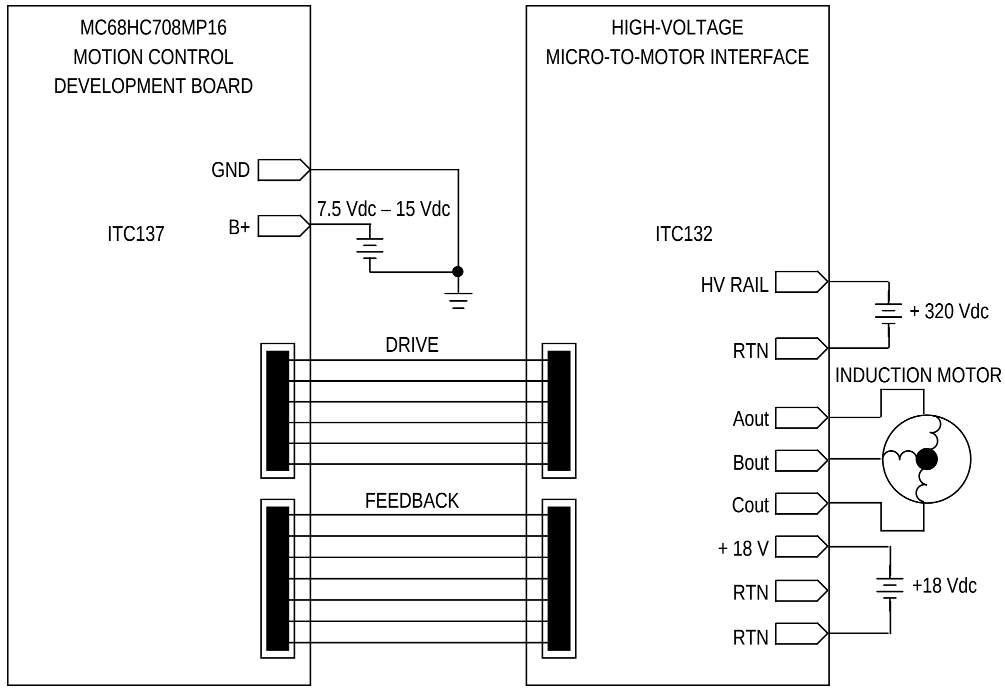

Figure 8. Application Example

Design Considerations

The ac induction motor drives are relatively complex internal to the processor in terms of code, processing power, and the PWM timer's hardware. Brushless dc motor drives tend to be more complex external to the processor, particularly with regard to noise management of the sensor inputs. A number of design considerations that cover operation with both types of motors are discussed here.

Sensor Inputs

For brushless motors that use sensor inputs for commutation, noise immunity of the sensor inputs is a key design consideration. Noise on these inputs can be particularly troublesome, since commutating to the wrong state can jerk the motor and increase power dissipation. To facilitate noise robust sensor inputs, Schmitt triggers have been placed between the Hall sensor input connector and the processor. Hysteresis makes the Schmitt trigger significantly more robust than using input ports directly. In addition, these signals are filtered with 100 ns single pole filters. Using relatively low value pullup resistors, on the order of 1 kΩ, provides an additional measure of noise immunity.

The way that the code is written also has an important influence on noise robustness. Since the sequence of commutation is known, based upon the state of the forward/reverse input, it is relatively easy to detect an out-of-sequence Hall sensor input. Generally speaking, when this occurs it is desirable to turn all the power transistors off until a valid Hall code is received.

Lockout

Especially on a machine that will be used for code development, it is desirable to prevent simultaneous conduction of upper- and lower-power transistors in the same phase. This feature is built into the HC708MP16's PWM timer. Once the timer has been initialized correctly, simultaneous conduction of a top and bottom output transistor in the same phase is locked out. Code errors that occur after initialization is completed will, therefore, not destroy power stage output transistors by turning on the top and bottom of one half bridge simultaneously. This arrangement also prevents simultaneous conduction in the event of a noise induced software runaway.

Dead Time

In induction motor drives, providing dead time between turn-off of one output transistor and turn-on of the other output transistor in the same phase is an important design consideration. Dead time is also a feature that is built into the HC708MP16's PWM timer. It is programmable, to accommodate a variety of gate drives and output transistors. In the software 2 μs of dead time has been selected for operation with ITC132 power stages.

Power-Up/ Power-Down

When power is applied or removed, it is important that top and bottom output transistors in the same phase are not turned on simultaneously. Since the outputs are low when unpowered, sequencing is important in opto-coupled drives where the ITC137 output directly drives opto couplers. To ensure proper sequencing, a switched +5 is provided for sourcing drive current to the opto's. This supply is held off until RESET occurs and input voltage is high enough for safe operation. Connection to an opto input is illustrated in **Figure 9**. It applies to operation with an ITC132 power stage.

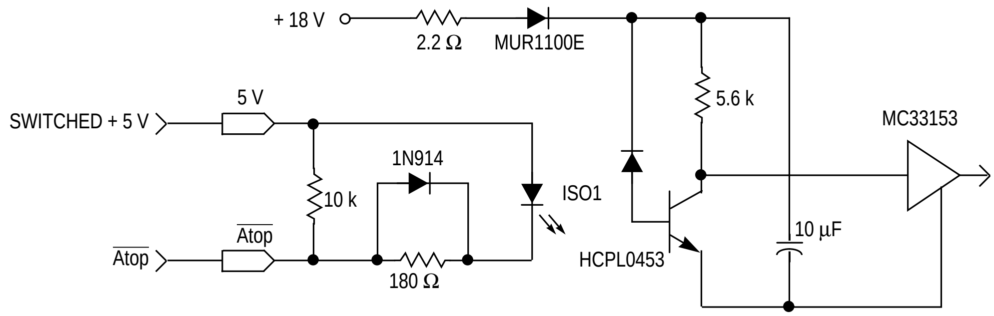

Figure 9. Connection to an Opto-Coupled Output Stage

Grounding

Last but not least, board layout is an important design consideration. In particular, how grounds are tied together influences noise immunity. In order to maximize noise immunity, a two section digital ground plane and a separate analog ground trace that intersects the digital ground plane at just one point are used. The digital ground plane (GND) is common to the power supply return and serves as a general-purpose ground. It is sectioned around the PWM timer's outputs to keep the relatively high return current associated with the outputs from flowing all over the board. An analog ground (AGND) ties the speed control input return and op amp signal grounds together before connecting with digital ground at only one point. AGND also runs as a separate trace to pins 14 and 16 of FEEDBACK connector J2.

Demonstration Software

Software included with the ITC137 motion control development board provides basic ac induction motor control. It is intended to use with an ITC132 high-voltage micro-to-motor interface, as shown in **Figure 8**. Firmware for this application is programmed into the MC68HC708MP16 for immediate use. Source code is also provided on diskette. Open loop volts per Hertz drive from 0 to 120 Hz and PWM rates of 1800 to 28,800 Hz are supported. Other options include sine, third harmonic injection, or space vector modulation waveforms, full modulation at 60 or

120 Hz, run/stop and direction control. Two different operating modes are possible with the supplied software: stand alone mode and terminal mode.

Stand Alone Mode

When the ITC137 is initialized after reset, it is operating in stand alone mode. In this mode, all options (speed, direction, etc.) are read from controls on the board. Since the software ensures coordination of the actual changes in PWM, voltage, etc., changes may safely be made in real time while driving a motor. One exception to this is if the motor load has a large amount of inertia. In this case, the rate of speed change allowed by the software may not be slow enough to prevent regeneration of excessive dc bus voltage.

User settings are:

- SPEED, or drive frequency, is determined by speed potentiometer R2. Frequency may be set from 0 to 120 Hz in 1-Hz increments. Large changes are not instantly applied; instead a slow ramp to the new setting is implemented.
- FORWARD/REVERSE sets the drive direction. When direction is reversed, speed is ramped down to 0 then ramped up to the current speed setting in the new direction.
- RUN/STOP allows speed to be forced to 0. Speed is ramped to 0 when stop is selected, then rammed up to the current speed setting when the switch is returned to RUN.
- DIP SWITCH SETTINGS — Additional operating options are controlled by a 5-position DIP switch, SW1. Position 1 determines the frequency of 100 percent voltage modulation, OFF for full voltage at 60 Hz, and ON for full modulation at 120 Hz. Position 2 determines the waveform, OFF for sine, and ON for third harmonic injection. PWM rates are determined by positions 3, 4, and 5 as shown in **Table 3**.

Table 3. PWM Rates

DIP 3	DIP 4	DIP 5	PWM Rate
On	On	On	2000
On	On	Off	4000
On	Off	On	8000
On	Off	Off	12,000
Off	On	On	16,000
Off	On	Off	18,000
Off	Off	On	20,000
Off	Off	Off	22,000

Terminal Mode

The ITC137 serial port, labeled SCI, is also enabled and monitored for activity. A terminal or terminal emulation software running on a personal computer (PC) will communicate with this port. Any basic serial communications software that is set for 9600 baud, eight data bits, no parity, and one stop bit, will work.

When commanded to do so via the terminal, the ITC137 can be switched to terminal mode, where all control is by keyboard entries. This can be done in real time without disturbing motor drive parameters. When terminal mode is activated, it uses the ITC137 hardware settings as defaults, and when deactivated, settings revert to the hardware.

To connect the ITC137 to an IBM-compatible PC, follow these steps:

1. With power removed from the ITC137 and the PC off, connect a 9-connector straight through cable from the ITC137 connector labeled SCI to the COM1 or COM2 serial port of the PC. PC serial ports are wired as DTE (data terminal equipment) and the ITC137 SCI port is wired as DCE (data communications equipment). This is why a 9-conductor cabled wired straight through must be used. Do not use a null modem cable.
2. Restore power to the ITC137 and PC.

3. If you are using DOS-based communications software such as ProComm™, set the COM port to COM1 or COM2 depending on which PC port you have cabled to the ITC137. Set the baud rate to 9600, the number of data bits to eight, the number of stop bits to one and the parity to none. Set the duplex to full duplex.
4. If you are using Windows® or Windows 95®, a terminal program is included in the accessories. Start the terminal program, open the setting pulldown menu, and select communications. Set the options as listed in step 3.
5. Reset the ITC137 board. If connected and configured properly, the terminal will display software version information and the top level command menu shown in **Figure 10**.

Keyboard activity will have no effect until the control mode command is used to set terminal mode. In this mode, further inputs from the ITC137 hardware controls are ignored. The initial settings will be identical to the hardware settings at the time control is transferred. When control is returned to stand alone mode, settings will revert to the hardware settings, including a gradual ramp to the speed control potentiometer setting. Thus transfer between the two modes may be made while driving a motor.

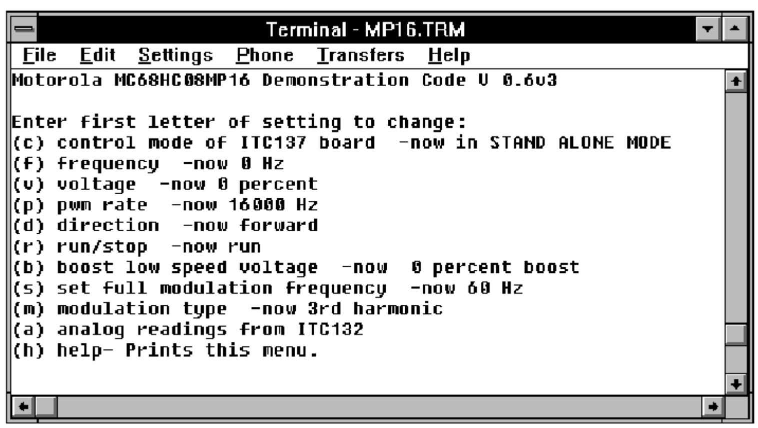

Figure 10. Terminal Display

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Terminal Mode Main Menu

The main menu, shown in **Figure 10**, allows the following command options. Note that commands are executed when followed by an ENTER keystroke.

Control mode (c)

Chooses between stand alone mode, with ITC137 board controls and terminal mode with all control via terminal commands

Frequency (f)

Sets drive frequency from 0 to 120 Hz

Voltage (v)

Temporarily overrides the normal volts per Hertz setting with a new voltage. Voltage will change instantly.

WARNING: *Large voltage jumps or setting a large voltage at a low frequency can damage power transistors.*

PWM rate (p)

Chooses a PWM carrier frequency between 1800 and 28,800 Hz

Direction (d)

Selects forward or reverse

Run/Stop (r)

Selects run or stop

Boost (b)

Chooses a low-frequency voltage boost of up to 20 percent

Set full modulation frequency(s)

Selects a 100 percent modulation point of 60 Hz or 120 Hz. Voltage will change instantly between these two slopes.

WARNING: *Note that large voltage jumps can be hazardous to power stages.*

Modulation type (m)

Chooses between sine, sine plus third harmonic injection or space vector modulation (SVM) waveforms. In order to experiment with any SVM modulation type containing V0 nulls with an ITC132 power stage, the bootstrap circuit should be modified. At least 220 µF of additional bootstrap capacitance on each phase is needed for adequate hold up time. Pads are provided on ITC132 boards for this purpose. Therefore, it is not advisable to select type V0; or V0, V7; or V7, V0 from this menu when using an unmodified ITC132 board.

Analog readings (a)

Enables or disables on-screen display of bus voltage, bus current, and temperature information

Software Functional Overview

The core function of the demonstration code is to synthesize three phase waveforms for variable frequency drive of ac induction motors. This task is simplified greatly by the 6-channel motor control PWM unit on the MC68HC807MP16. In general, waveforms are synthesized by looking up values in a table for each point along a curve and then converting these values to PWM duty cycles. The repetition rate, or carrier frequency, determines how many data points define the curve. Drive frequency, typically 0 to 120 Hz, is determined by how rapidly the microprocessor steps through the table values.

The timebase for this process is the rate at which the PWM unit interrupts the HC08 CPU. If the PWM unit is configured to interrupt every cycle, this rate is identical to the carrier frequency. It is common practice to service the PWM unit less often than this at higher carrier frequencies. This entire process is performed three times upon each interrupt to create three waveforms that are each offset 120 degrees.

Only about 1800 bytes of code are needed for this basic operation. The user terminal interface, additional demonstration features, and factory test routines use about 11,000 bytes. The code is modular and written in C language (except for the SINESCALE routine), in order to encourage experimentation and reuse. A brief summary of each module is listed as follows. Consult and C source code for complete details.

MAIN

- Initializes PWM and SCI units
- Resets communication, A/D data, and waveform data table pointers
- Enables interrupts for PWM and communication
- Enters SCAN loop

PWM

- PWM interrupt handler
- Services COP
- Passes data table pointer to QUADZ for each phase
- Loads PVALX registers from global RAM value pwmmod
- Exchanges two phases if reverse direction is set
- Maintains waveform data table pointers
- Sets PWM unit LDOK bit

QUADZ

- Accepts waveform data table pointer
- Translates full waveform pointer into quadrant pointer
- Selects sine or third harmonic injection according to settings
- Calls SINSCALE to scale table value with global RAM value vscale
- Modifies global RAM value pwmmod

SINSCALE

- Accepts waveform data and scaling value
- Scales with 24-bit accuracy
- Returns integer formatted for use in PVALX registers

SVM

- Accepts waveform data table pointer
- Calculates SVM time segments via CALCULATE function
- Modifies PWM PVALX registers

CALCULATE

- Calculates times for SVM modulation

SCAN

- Scans hardware for speed, PWM, etc., settings
- Scans serial communication buffer for commands via GETCH
- Parses commands, sets control flags
- Calls RECALC to execute setting changes
- Calls MENU to reflect changes back to terminal user

RECALC

- Recalculates correct PWM modulus, load frequency, and interrupt frequency
- Recalculates correct data table pointer increment value
- Updates PWM registers and RAM variables coherently with interrupt mask

MENU

- Transmits command menus and current settings to terminal user

RECEPT

- SCI interrupt handler writes to buffer
- Maintains pointer

PUTCHAR

- SCI transmit

GETCH

- Parses input string in buffer

Software Development

The ITC137 may be used in an emulation environment with Freescale MMDS08 or MMEVS08 development tools. Executable code in S-record format is included on the source code diskette. The development system flex cable can be connected directly to the ITC137 without the use of a target head adapter by following these steps:

1. Ensure all power is removed from the development tool (MMDS08 or MMEVS08), the ITC137 board, and the ITC132 board.
2. Remove the MC68HC708MP16 processor on the ITC137 board from its socket.
3. Attached the development tool M68CBL05C flex cable directly to the ITC137 using the headers next to the processor's socket.
4. Restore power to the development tool and the ITC137 board.

CAUTION: *Do not restore power to the ITC132 high-voltage rail at this point.*

5. Following development tool instructions, download the demonstration code S records or code of your own creation and run it.
6. Using an oscilloscope, probe the PWM top and bottom output test points provided on the ITC137.
7. Restore power to the motor rail only after verifying that ITC137 output waveforms are correct.

CAUTION: *Power must be removed in the exact reverse of this sequence when shutting down or power stage IGBTs may be damaged.*

Additional Precautions

It is very important to note that emulator operations such as stopping emulation or setting breakpoints can over-stress power stages. If, for example, the emulator is stopped in a state that energizes the motor, the relatively low winding resistance in most ac motors will allow excessive current to flow. Under these circumstances, it is relatively easy to over-stress power devices. Any software change, no matter how minor, should be checked out with the above procedure before applying power to the motor.

Application Note

Conclusion

The ITC137 controller is part of a tool set that facilitates motor drive development. It allows the 68HC708MP16 processor's performance to be verified in many applications without the need for building hardware or developing software. ITC137 controllers interface with MMDS08 and MMEVS08 development tools for writing code, with ITC122 and ITC132 power stages for energizing motors and with serial port terminals for changing motor control parameters real time. In addition, both hardware design and source code can be used as references for speeding product development.