

# AN1624

## ITC137 68HC708MP16 Motion Control Development Board

By Jim Gray, Bill Lucas and Warren Schultz

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.

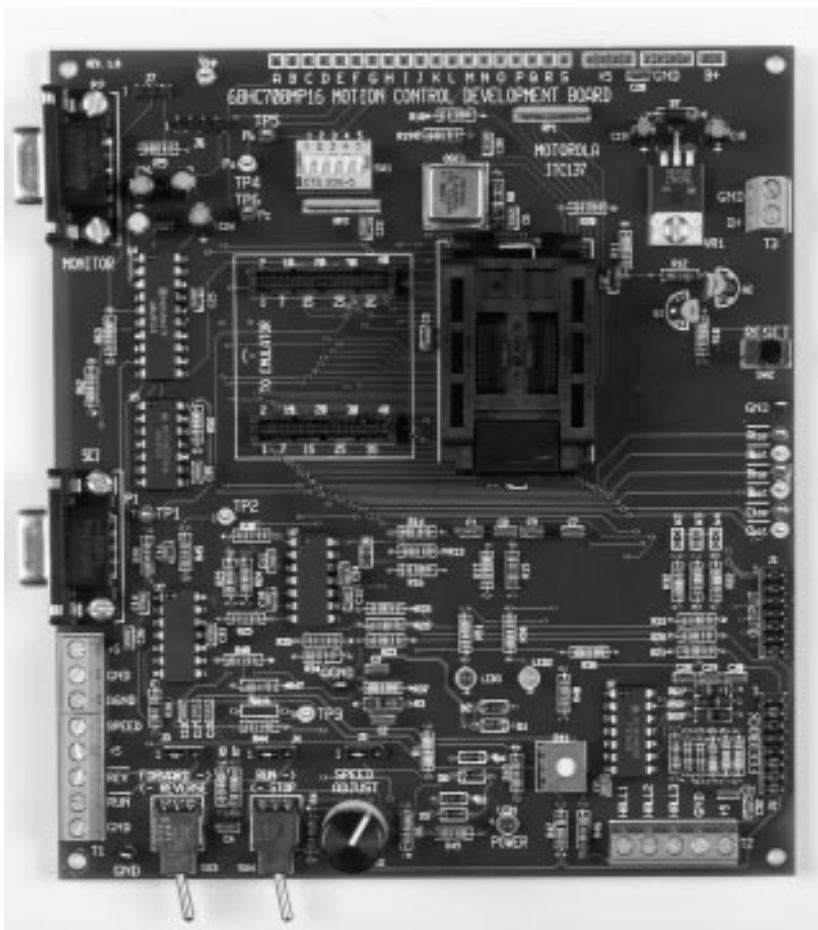


Figure 1. ITC137 Development Board

### 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.

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Inputs are accepted from switches and a pot on the board or external RUN/STOP, FORWARD/REVERSE, and SPEED signals. The speed input is a 0 to +5 volt signal with zero volts corresponding to zero speed, and 5 volts producing full speed. RUN/STOP & 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 following electrical characteristics 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 ITC132	B+	7.5 7.5		28 15	Volts Volts
Power Supply Voltage	+5	4.75		5.25	Volts
Min Logic 1 Input Voltage	V <sub>IH</sub>		2.7		Volts
Max Logic 0 Input Voltage	V <sub>IL</sub>		2.0		Volts
Quiescent Current	I <sub>CC</sub>		80		mA
SPEED Input	V <sub>SPEED</sub>		20		%/Volt
Buffer Gain V <sub>temp</sub> V <sub>bus</sub> I <sub>sense</sub>	A <sub>V</sub> (V <sub>temp</sub> ) A <sub>V</sub> (V <sub>bus</sub> ) A <sub>V</sub> (I <sub>sense</sub> )		-16.9 2 2		
Output Sink Current				25	mA

### Content

Board contents are described in the following schematic and parts list. A pin by pin circuit description follows in the next section.

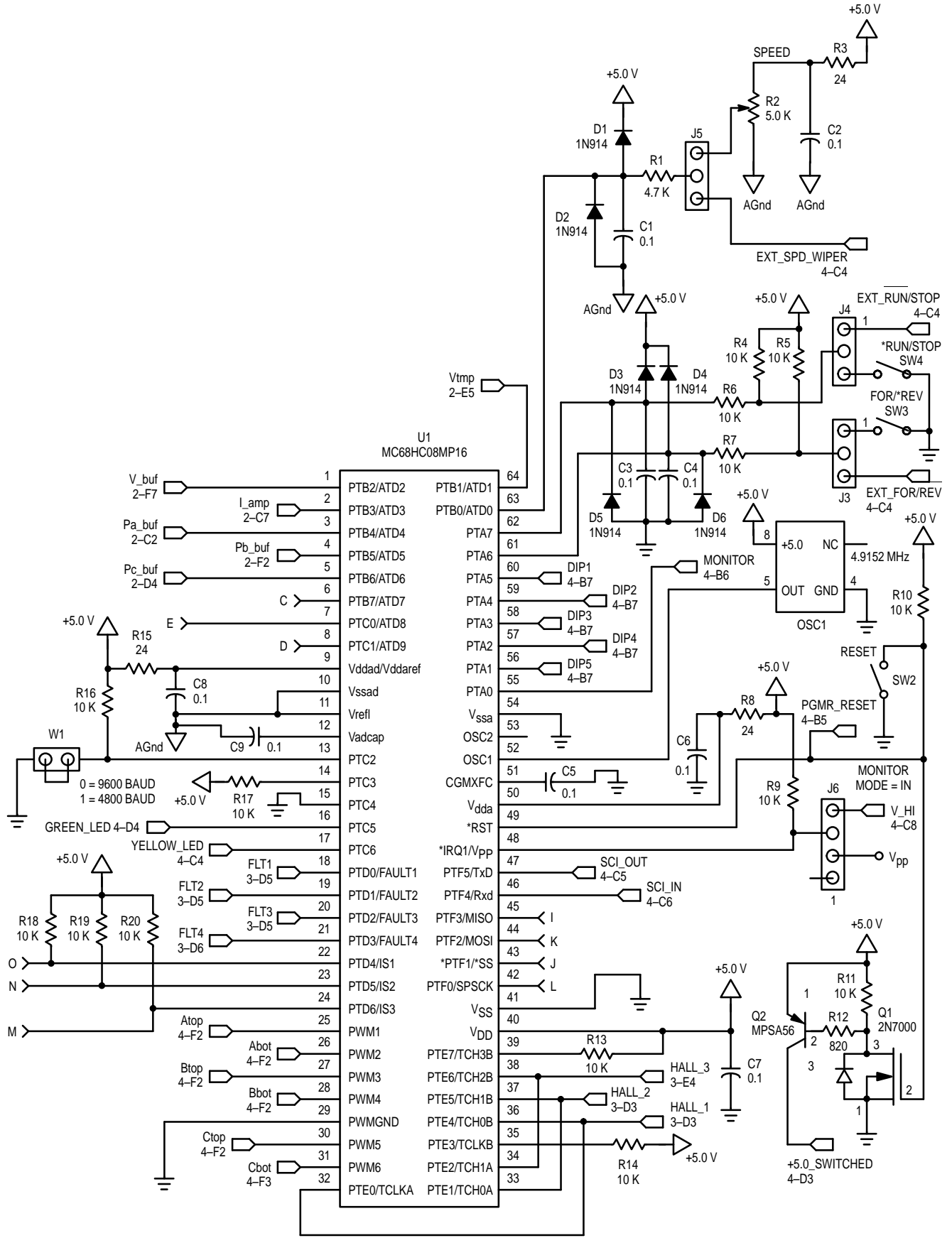


Figure 2. Schematic

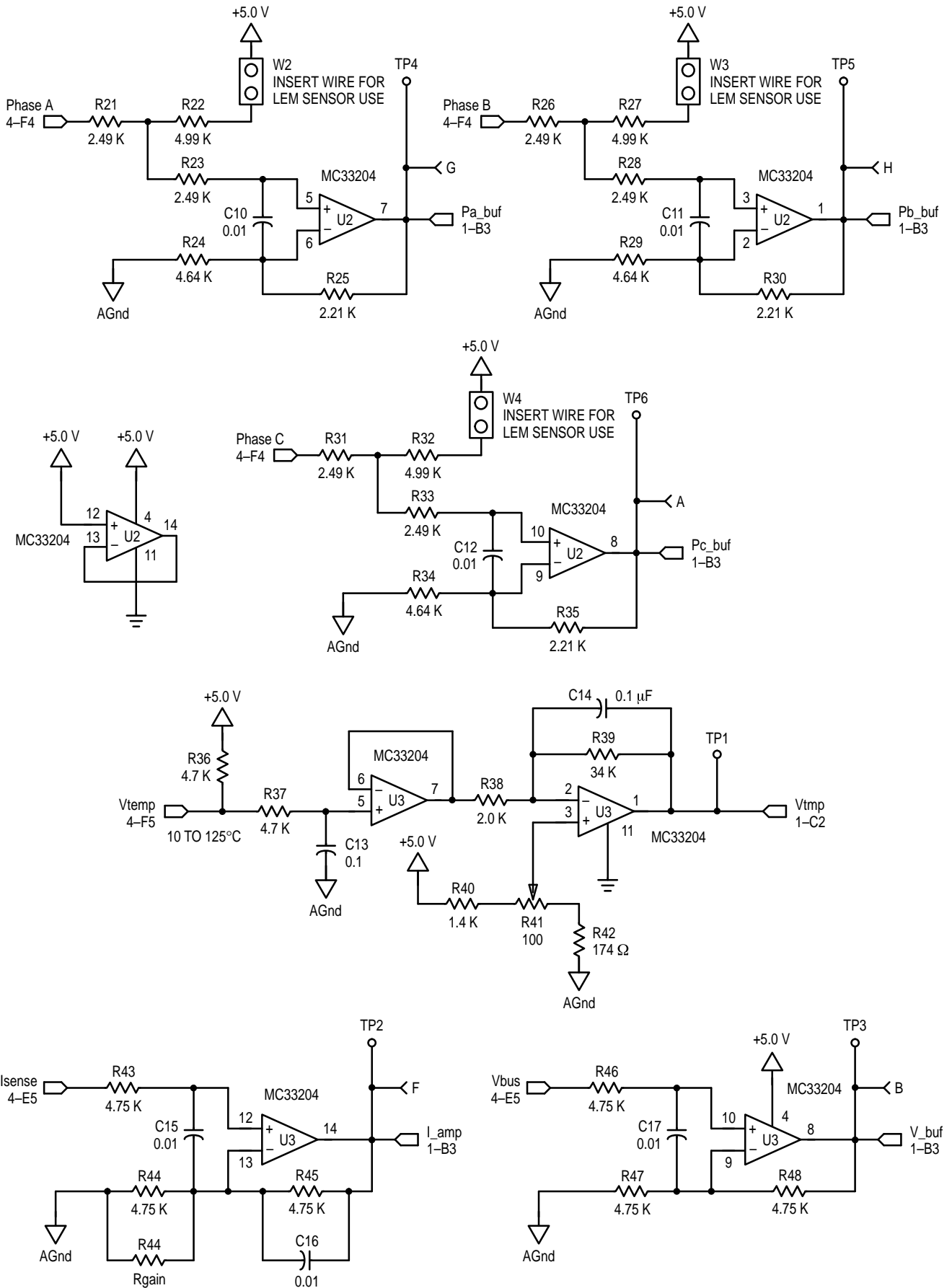


Figure 3. Schematic

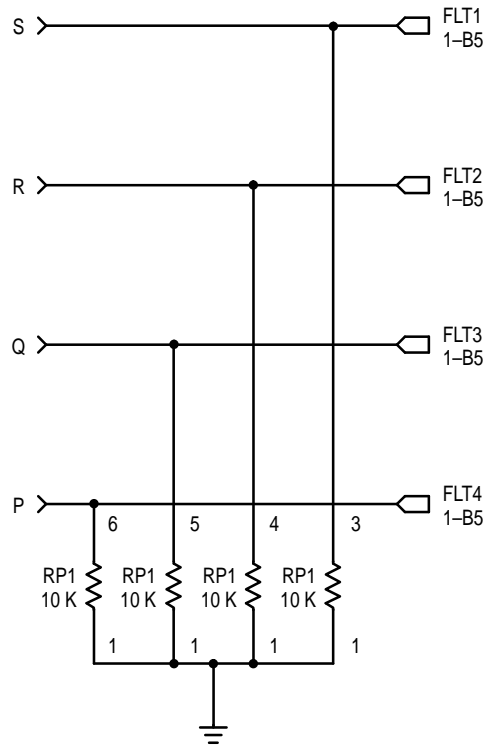
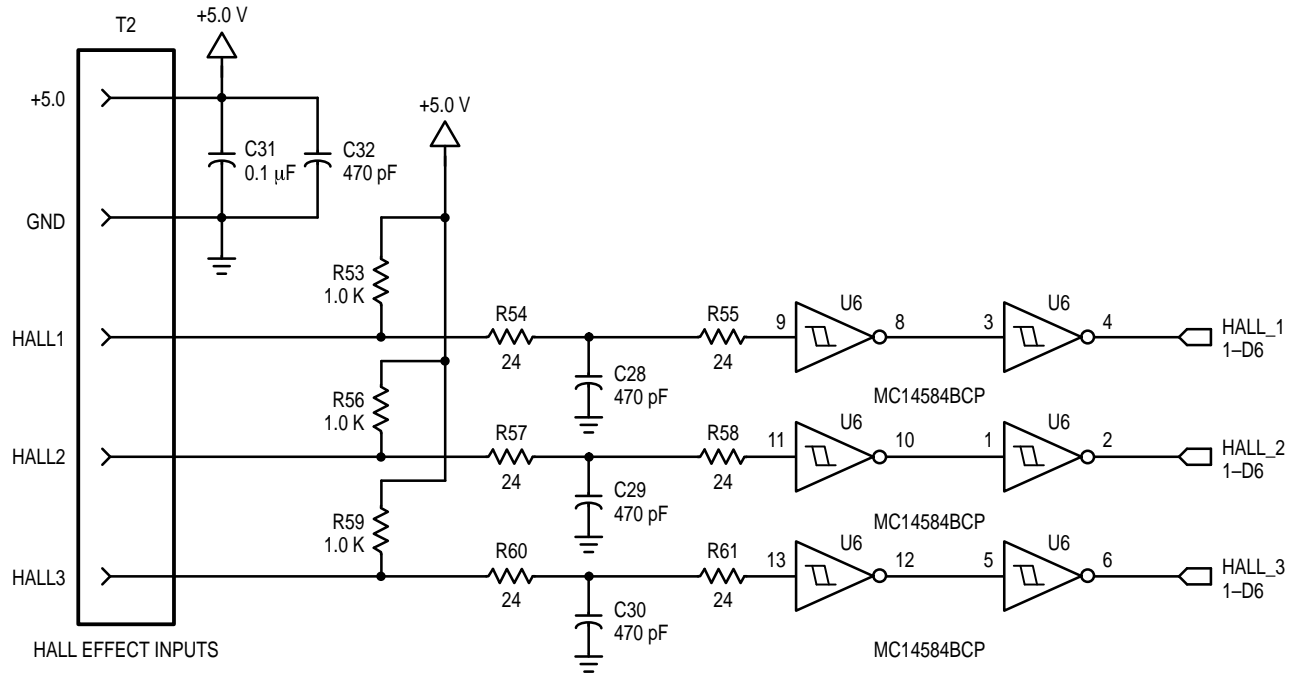


Figure 4. Schematic



Table 2. Parts List

Designators	Qty	Description	Manufacturer	Part Number
C1–C9,C13,C14,C20–C22				
C25,C31,C33–C38	22	.1µf Capacitor	Sprague	1C105Z5U104M050B
C10–12,C15–C17	6	.01µf Capacitor	Sprague	1C105Z5U103M050B
C18,C19	2	1 uF Electrolytic Cap	Mepco–Centralab	CN15A220K
C23,C24,C26,C27	4	10 uF Electrolytic Cap	Digi–Key	P5272
C28–C30,C32	4	470 pf Capacitor	Sprague	1C105Z5U471M050B
D1–6	6	Small Signal Diode		1N914
D7	1	General Purpose Diode	Motorola	1N4002
J1	1	2x7 .1o.c. Jumper Block Note: 2	Digi–Key	S2011–36–ND
J2	1	2x8 .1o.c. Jumper Block Note: 2	Digi–Key	S2011–36–ND
J3, J4, J5,J7	4	1x3 .1o.c. Jumper Block Note: 3	Digi–Key	S1011–36–ND
J6	1	1x4 .1o.c. Jumper Block Note: 3	Digi–Key	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	A2100–ND
Q1	1	Small signal FET Transistor	Motorola	2N7000
Q2	1	Small signal PNP Transistor	Motorola	MPSA56
RP1,RP2	2	10k Ohm 6 pin SIP resistor pack	Digi–Key	770–61R10K–ND
R2	1	5k Ohm Variable resistor	Clarostat	392JB–5k0–S
R4–R7,R9,R10,R11,R13,R14				
R16–R20,R52,R62,R63	17	10k Ohm resistor	Yageo	
R12	1	820 Ohm Resistor	Yageo	
R21,R23,R26,R28,R31,R33	6	2.49K Ohm resistor 1%	Yageo	
R22,R27,R32	3	4.99K Ohm resistor 1%	Yageo	
R24,R29,R34	3	4.64K Ohm resistor 1%	Yageo	
R25,R30,R35	3	2.21K Ohm resistor 1%	Yageo	
R1,R36,R37	3	4.7k Ohm resistor	Yageo	
R38	1	2.00K Ohm resistor 1%	Yageo	
R39	1	34.0K Ohm resistor 1%	Yageo	
R40	1	1.40K Ohm resistor 1%	Yageo	
R41	1	100 Ohm Trim–pot	Digi–Key	3386P–101–ND
R42	1	174 Ohm resistor 1%	Yageo	
R43–48	6	4.75K Ohm resistor 1%	Yageo	
R49	1	470 Ohm Resistor	Yageo	
R50,R51,R53,R56,R59	5	1K Ohm Resistor	Yageo	
R3,R8,R15,R54,R55				
R57,R58,R60,R61	9	24 Ohm Resistor	Yageo	
SW1	1	5 POS DIP SWITCH	CTS	CT2065–ND
SW2	1	SPST Pushbutton 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

Table 2. Parts List (continued)

Designators	Qty	Description	Manufacturer	Part Number
T3	1	2 Screw Terminal Connector	Phoenix Contact	MKDSN 1,5/2-5,08
U1	1	Microprocessor	Motorola	MC68HC708MP16
U1X	1	QFP 64 pin Socket	Prine Distributors	FPQ-64-0.8-10A
U2,U3	1	Quad Op-Amp	Motorola	MC33204P
U4	1	RS-232 Driver/Receiver	Motorola	MC145407P
U5	1	Quad Bus Driver	Motorola	MC74HC125P
U6	1	Hex Schmitt Trigger	Motorola	MC14584BCP
VR1	1	Voltage Regulator	Motorola	MC7805ACT
OSC1	1	4.9152 MHz Oscillator	Digi-Key /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,Vpp	7	Test Point Yellow	Components Corp.	TP-104-01-04
No Designator	1	4-40 x 1/4" Screw for VR1		
No Designator	1	4-40 Nuts for VR1		
No Designator	5	Shorting Jumpers for J3-J7	Digi-Key	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 3 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 6 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.

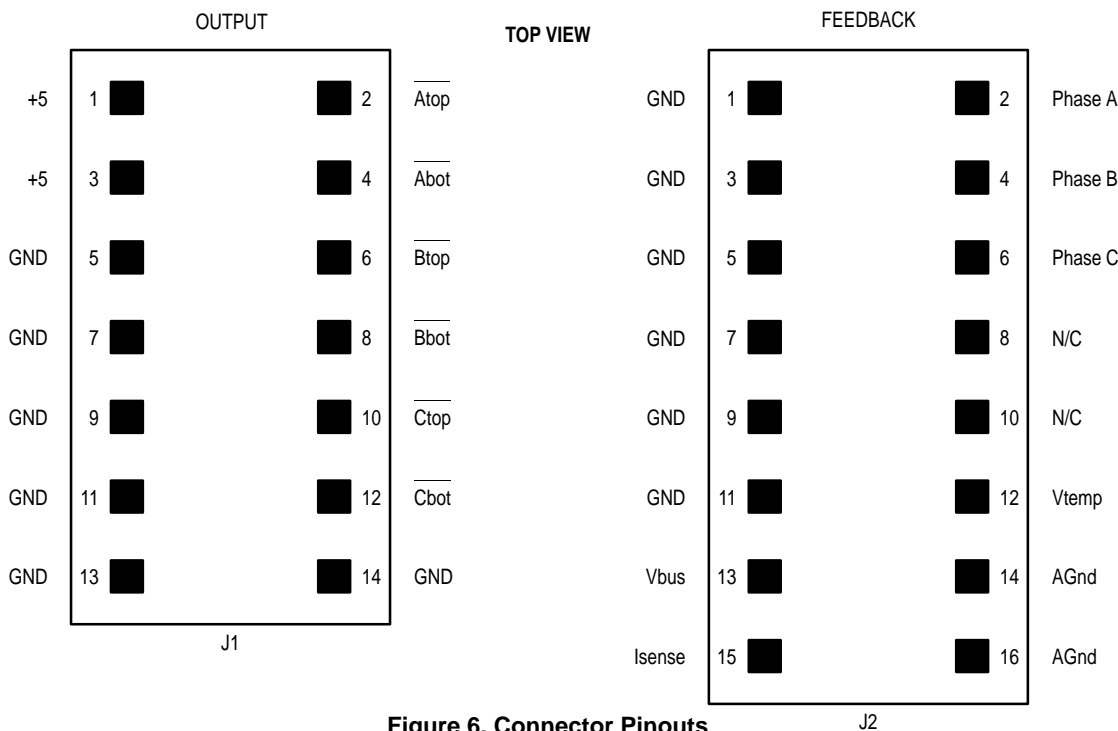


Figure 6. Connector Pinouts



**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 zero to 5 volt analog signal. Zero volts corresponds to zero 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 pot. As shipped, J5 is set to control speed from the pot.

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.

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**

Isense:

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.

Vbus:

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.

Vtemp:

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, & 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 & 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, & 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.

Atop – 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 de-bug for the HC708MP16.

**Test Points**

TP1 – TP3:

Test points TP1, TP2, & 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, & TP6 provide access to buffered feedback signals from feedback connector J2 pins 2, 4, & 6.

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### GND & 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 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 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.

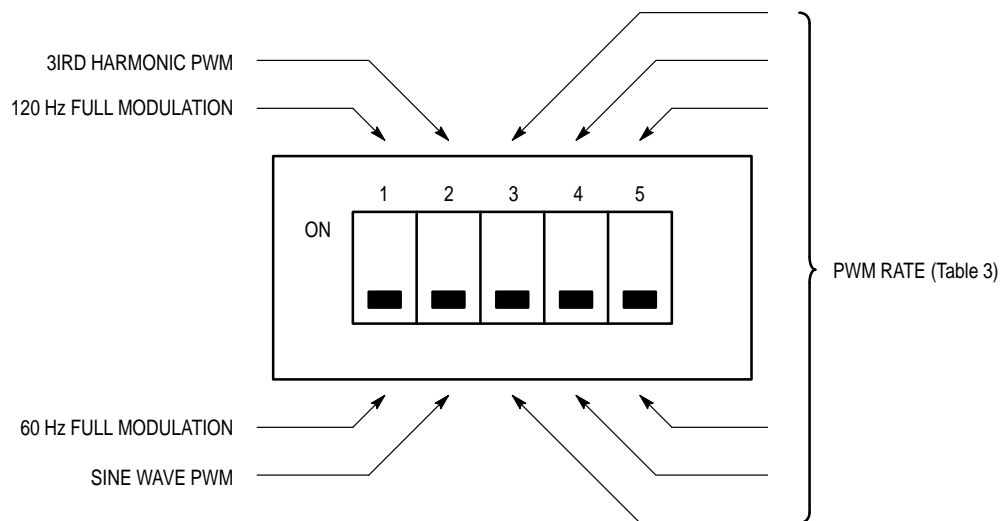


Figure 7. Switch 1

## Potentiometers

### R2:

R2, labeled SPEED ADJUST, is the speed control pot. 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 pot that is used for adjusting the analog signal that represents temperature. Setting the voltage at test point TP1 to 1 volt at 25 degrees C with this pot 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 2, and its input at Feedback Connector J2 pin 15. 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 \*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 10k ohm resistor.

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

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

P:  
Pad "P" is connected to the processor's FAULT4 input pin. This signal is pulled to logic ground through a 10k ohm resistor.

Q:  
Pad "Q" is connected to the processor's FAULT3 input pin. This signal is pulled to logic ground through a 10k ohm resistor.

R:  
Pad "R" is connected to the processor's FAULT2 input pin. This signal is pulled to logic ground through a 10k ohm resistor.

S:  
Pad "S" is connected to the processor's FAULT1 input pin. This signal is pulled to logic ground through a 10k ohm 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.

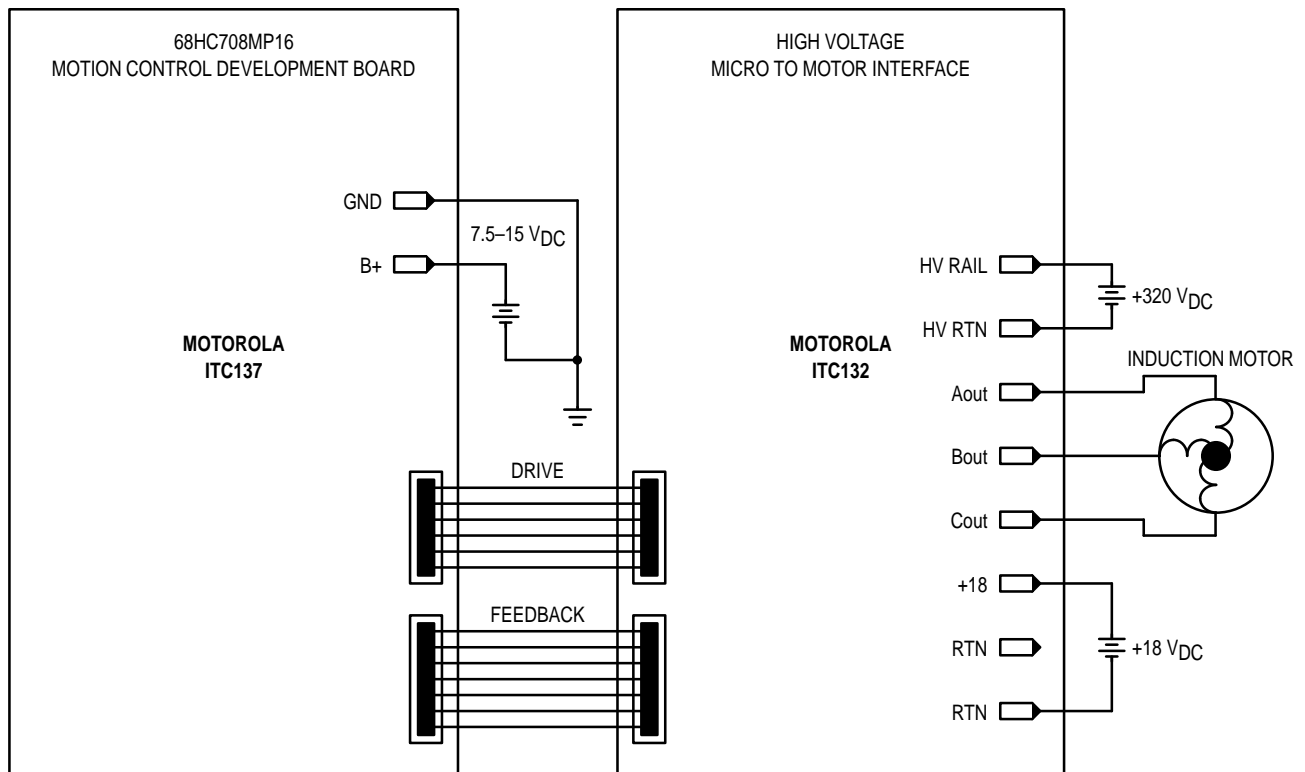


Figure 8. Application Example

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A three 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.

### DESIGN CONSIDERATIONS

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 as follows.

#### 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 nsec single pole filters. Using relatively low value pull up resistors, on the order of 1K ohms, 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 usec 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 insure 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.

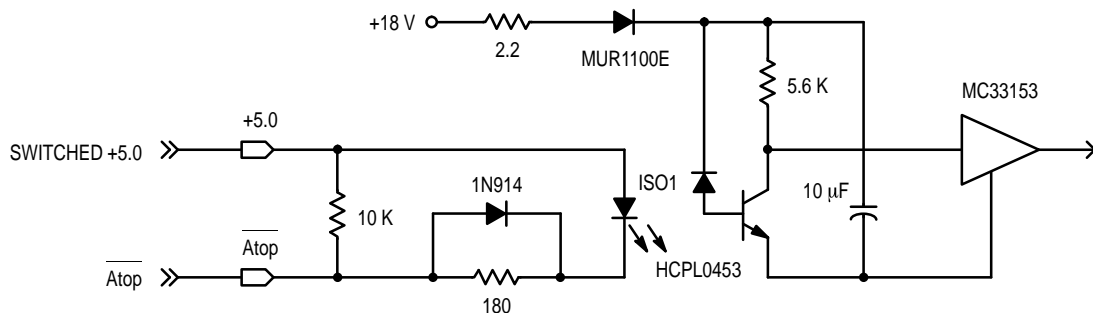


Figure 9. Connection to an Opto Coupled Output Stage

#### 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 for 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 120Hz, 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:

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 zero then ramped up to the current speed setting in the new direction.

RUN/STOP allows speed to be forced to zero. Speed is ramped to zero when stop is selected, then rapped up to the current speed setting when the switch is returned to RUN.

#### DIP SWITCH SETTINGS:

Additional operating options are controlled by 5 position DIP switch, SW1. Position 1 determines the frequency of 100% 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 follows:

**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	12000
OFF	ON	ON	16000
OFF	ON	OFF	18000
OFF	OFF	ON	20000
OFF	OFF	OFF	22000

## 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, 8 data bits, no parity, and 1 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 back to the hardware.

### CONNECTING THE ITC137 TO AN IBM COMPATIBLE PC

1. With power removed from the ITC137, and the PC off, connect a 9 conductor 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 cable 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 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 8, the number of stop bits to 1 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 settings pull down 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.

```

Terminal - MP16.TRM
File Edit Settings Phone Transfers Help
Motorola MC68HC08MP16 Demonstration Code V 0.6v3

Enter first letter of setting to change:
(c) control mode of ITC137 board -now in STAND ALONE MODE
(f) frequency -now 0 Hz
(v) voltage -now 0 percent
(p) pwm rate -now 16000 Hz
(d) direction -now forward
(r) run/stop -now run
(b) boost low speed voltage -now 0 percent boost
(s) set full modulation frequency -now 60 Hz
(m) modulation type -now 3rd harmonic
(a) analog readings from ITC132
(h) help- Prints this menu.

```

Figure 10. Terminal Display

### 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 Hertz.

Voltage (v):

Temporarily overrides the normal Volts per Hertz setting with a new voltage. Voltage will change instantly. **Note that large voltage jumps or setting a large voltage at low a frequency can damage power transistors.**

PWM rate (p):

Chooses a PWM carrier frequency between 1800 and 28800 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%.

Set Full Modulation Frequency (s):

Selects a 100% modulation point of 60 Hz or 120 Hz. Voltage will change instantly between these two slopes. **Note that large voltage jumps can be hazardous to power stages.**

Modulation Type (m):

Chooses between sine, sine plus 3rd 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 uF 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 MC68HC708MP16. 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 time base 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 the '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 3rd harmonic injection according to settings
- Calls SINSSCALE to scale table value with global ram value vscale
- Modifies global RAM value pwmmod

## SINSSCALE:

- 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 Motorola 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 the steps below:

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. Attach 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. **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.

**NOTE: POWER MUST BE REMOVED IN THE EXACT REVERSE OF THIS SEQUENCE WHEN SHUTTING DOWN OR POWER STAGE IGBT's 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.

## 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 & 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 a references for speeding product development.

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