ACPM750

Version 3.4

**Power Module
for
DC Brushless,
DC Brush
AC Motors**

TECHNOSOFT

DSP Motion Solutions

User Manual

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ACPM750
User Manual

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Read This First

About This Manual

This book describes the power module **ACPM750 version 3.4**. The ACPM50 v3.4 is a 750W-power module that can be used to drive DC brush, brushless DC and AC motors. Due to the MC-Bus compatible interface for the control unit, the ACPM750 v3.4 can be easily connected with all Technosoft DSP-based modules equipped with 5V-based MC-Bus interface.

Information about Cautions

This book may contain cautions.

> **CAUTION!**
> **THIS IS AN EXAMPLE OF A WARNING STATEMENT.**
> **A WARNING STATEMENT DESCRIBES A SITUATION THAT COULD POTENTIALLY CAUSE HARM TO YOU OR TO THE ACPM750 V3.4 POWER MODULE**

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Note: You need to register your ACPM750 v3.4 system in order to get free assistance and support:

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This equipment is intended for use in a laboratory test environment only. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to subpart J of part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the users at their own expense will be required to take whatever measures may be required to correct this interference.

Important warning

CAUTION!
Please read this entire manual before making any connection. There are high voltages and currents involved, and any mistake could be very destructive or deadly.

If you are not sure how to make connections to the unit, please contact Technosoft BEFORE applying power to the unit.

Contents

1. Introduction

This chapter provides a general description of the ACPM750 v3.4 power module along with a block diagram and the key features

Contents

1.1. ACPM750 v3.4 Overview

The ACPM750 v3.4 is a 750-W MC-Bus compatible power module, which combined with a control unit, allows to drive the following categories of motors:

- brushless DC motors
- permanent magnet synchronous motors (PMSM)
- AC induction (asynchronous) motors

The ACPM750 v3.4 includes the following main components:

- 3-phase IGBT inverter: up to 400 V_{DC}, $4A_{RMS}$, 24kHz switching frequency
- Brake IGBT: up to $400V_{DC}$, $6A_{RMS}$ (brake resistor not provided)
- in-rush current limiter
- 2 currents feedback, measured from isolated transducers series with inverter outputs
- DC-bus voltage feedback
- Hall sensors inputs
- Differential or single-ended incremental encoder port
- Analog tacho-generator input with adjustable gain
- Analog reference (potentiometer)
- RS-232 serial communication connector
- Logical supply: $5V_{DC}$ / 1.3A
- Motor supply: $110V_{AC}$ tri-phase or $220V_{AC}$ mono-phase
- Protections to short-circuit, earth fault, over-current, over-voltage, over-temperature and accidental logic supply shutdown
- Error latch triggered by any error condition, reset by logic control
- Standard MC-Bus interface with the control unit

Through the MC-bus interface the control unit can:

- Independently command each of the 6 IGBT transistors of the inverter
- Drive a low-side IGBT connected to external brake resistor
- Receive a power stage error signal as soon as any of the protections are triggered
- Reset the error signal
- Read the motor currents and the DC-bus voltage
- Read the motor Hall signals
- Read the encoder quadrature signals A, B and the Index
- Read the analog tacho-generator feedback
- Read an external reference potentiometer
- Control the RS-232 serial communication

At MC-bus level, the IGBT transistor commands and the power stage error signal are 5V TTL/CMOS compatible. Bipolar signals, such as motor currents, are applied with 2.5V offset, e.g. with zero value at 2.5V.

Thanks to the MC-bus compatibility, the ACPM750 v3.4 can be easily connected with any Technosoft DSP-based control unit.

1.2. Block Diagram

Figure 1.1 presents the block diagram of the ACPM750 v3.4 including the main components.

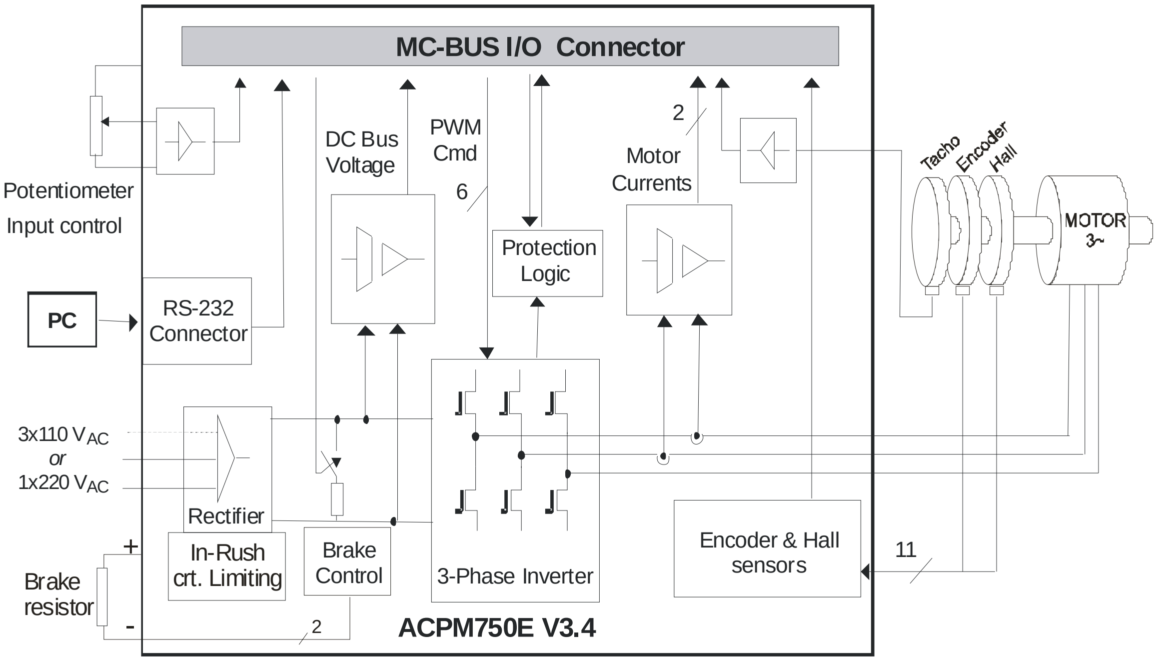


Figure 1.1. ACPM750 v3.4 Block Diagram

1.3. Key Features

- MC-bus compatible power module, easy connectable with any Technosoft DSP-based control module
- Suitable to drive brushless DC, brushless AC (PMSM) and asynchronous AC motors
- Logic supply: +5V_{DC} (±5%); 1.3A
- Motor supply: 90 – 240 V_{AC} mono-phase or 60 – 120 V_{AC} tri-phase
- Nominal output power: 750W, 150% overload for 1 minute
- Nominal current: 3.5A
- Peak current: 6A, for 1 minute
- Output voltage: 0 ÷ 230 V
- 3-phase ultra-fast IGBT inverter with switching frequency up to 24 kHz
- Protection to short-circuit (phase-phase), earth fault (phase-earth), over-voltage, under-voltage, overload (temperature sensor).
- Protection to logic supply under-voltage / accidental shutdown
- IGBT drive for external brake resistor
- In-Rush (start-up) current limit circuit
- Feedback signals for 2 motor currents
- Feedback for DC bus voltage
- Tacho-generator feedback input
- External reference (potentiometer) input
- Differential or single-ended encoder inputs
- Hall sensors inputs
- Standard MC-BUS interface with the control unit

1.3. Safety Information

Before to start working please read the following caution paragraph carefully.

CAUTION!

Never keep the power transistors permanently on, without commutation. In this situation the DC-bus voltage is applied directly to the motor and the higher current obtained <u>can damage the power module and the motor</u>. To avoid this situation please observe the following rules:

1. **Do not stop the timers or disable the interrupts used for motor control, when the PWM is active. To do safely one of these operations please disable the PWM outputs before.**
2. **If you are working under Code Composer:**
   a. **First check the code, in order to see if the used interrupts are enabled in debugging mode. See DBGIER register description in the DSP's manual.**
   b. **Check the code to see if the timer's initialization allows counting during "halt" state of DSP. See TxCON register description in the DSP's manual.**
   c. **Do not halt the DSP if the "Real-Time Mode" is disabled. Use "Debug | Real-Time Mode" menu command to enable this mode.**
   d. **Do not place a breakpoint or probe point in interrupt code.**
   e. **Do not define graphics.**
   f. **Enable the "Real-Time Mode" every time you open the Code Composer.**
3. **If you forgot to enable the "Real-Time Mode" and the motor control program is running, do not give the "Halt" command! For stopping, shut down the motor power supply.**

CAUTION!

Before the connecting / disconnecting any of the signals please turn off all power supplies. Else sever damage may occur.

CAUTION!

Be careful to correctly connect the logic power supplies polarity!
Reverse polarity will damage the ACPM750 module and the intelligent controller!

CAUTION!
Be careful to apply the right voltages to the AC power supply!
Using 220V_{AC} 3-phase with the ACPM750 v3.4 is NOT ALLOWED!
A too high input voltage will damage the ACPM750 module!

CAUTION!
Always connect the earth terminal input of the motor supply connector to a good grounding potential! If the earth pin is left unconnected, deadly potentials may be applied to the ACPM750 and to the operator!

CAUTION!
The brake transistor is NOT protected against short-circuits. Check the external brake resistor connections carefully, before activating the brake transistor!

CAUTION!
Do not touch the ACPM750 when the large red LED is lit. The ACPM750 area below the transparent cover contains high voltages that are dangerous for your life.

2. ACPM750 v3.4 Operation

This chapter describes the operation of the ACPM50 v3.4 power module. Information is provided on the ACPM750's various interfaces.

Contents

2.1. Board Layout

CAUTION!
BEFORE THE CONNECTING / DISCONNECTING ANY OF THE SIGNALS PLEASE TURN OFF ALL POWER SUPPLIES. ELSE SEVER DAMAGE MAY OCCUR.

Figure 2.1 presents the ACPM750 v3.4 board layout. Pin 1 for all the connectors and the jumper is marked on the layout with a square pad.

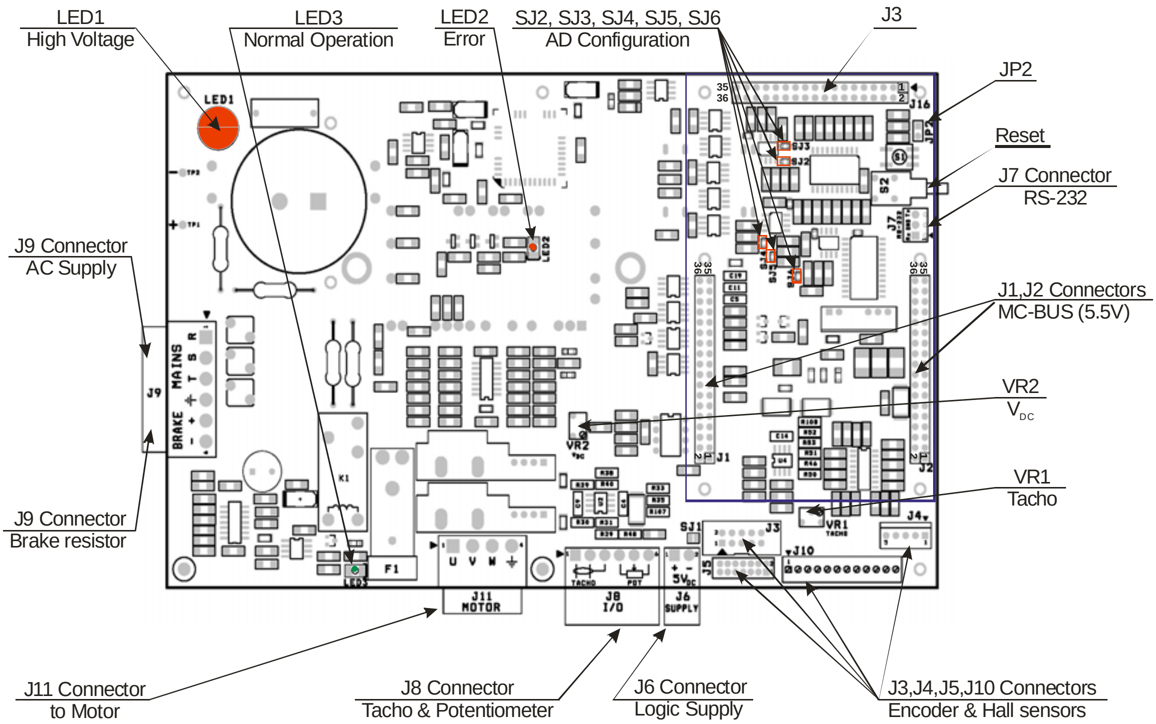


Figure 2.1. ACPM750 v3.4 Board Layout

2.2. Power Supply

The ACPM750 v3.4 requires two power supplies:

- **Logic supply:** $5V_{DC}$ ±5% (4.75 – 5.25 V_{DC}) for the internal logic; current consumption 1.3A
- **AC supply:** 90 – 220 V_{AC} (mono-phase) <u>or</u> 60 – 120 V_{AC} (tri-phase) for the motor

At power-on, the logic supply should be applied first.
At power-off, the logic supply should be removed last.

If this sequence is not respected, the braking transistor can be turned on spuriously during transient periods, and could damage the external braking resistor. The on-board protection against logic supply under-voltage / accidental shutdown will avoid any spurious turn-on of the main inverter IGBTs.

2.2.1. J6 – Logic Supply Connector

The logic power supply is used for on-board signal conditioning on the ACPM750 v3.4. This supply is also applied to the MC-Bus connectors in order to feed the intelligent control modules placed on the MC-Bus connectors.

The external logic supply must be regulated within a range of $4.75V_{DC}$ … $5.25V_{DC}$. The current requirement is $1…1.3A_{DC}$ for the ACPM750 v3.4, plus the consumption of the intelligent controller board(s) connected on the MC-Bus. Please consult the user manual of the appropriate intelligent controller for the consumption of this module, and add $1.2A_{DC}$ for the ACPM750 v3.4 to obtain the requirements of the external $+5V_{DC}$ supply.

CAUTION!
BE CAREFUL TO CORRECTLY CONNECT THE LOGIC POWER SUPPLIES POLARITY! REVERSE POLARITY WILL DAMAGE THE ACPM750 MODULE AND THE INTELLIGENT CONTROLLER!

The logic supply connector is a 2-pin 3.81mm pitch removable screw-terminal connector for the supply. Its pin assignment is presented in Table 2.1.

Table 2.1. *J6 – Logic Supply Connector*

Pin	Name	Type	Function
1	**+5V**	**I**	$+5V_{DC}$ logic supply plus (+)
2	**GND**	**I**	Logic supply ground (-)

2.2.2. J9 – AC Supply Connector

The AC power supply is applied to an on-board 3-phase rectifier and is delivered to the inverter as a DC voltage called “DC-bus”. The three input terminals (R, S and T) can be connected either to a 3-phase mains system, or to a standard mono-phased mains system.

When using a 3-phase system, all three input terminals R, S and T are used. The ACPM750 v3.4 accepts 3-phase input voltages between 60 and 120 V_{AC} (phase voltage, between phases and neutral point). The neutral point is not connected to the ACPM750 v3.4.

When using a mono-phase system, only two terminals (R and S) out of three are used. The “T” pin of the motor supply connector is left unconnected. In this configuration, the ACPM750 v3.4 accepts input voltages between 90 and 240 V_{AC}.

CAUTION!
BE CAREFUL TO APPLY THE RIGHT VOLTAGES TO THE AC POWER SUPPLY!
USING 220V_{AC} 3-PHASE WITH THE ACPM750 V3.4 IS NOT ALLOWED!
A TOO HIGH INPUT VOLTAGE WILL DAMAGE THE ACPM750 MODULE!

Regardless of the type of input mains system, the resulting rectified DC-bus voltage must remain within the range of 80 … 400 V_{DC}, and must be adapted to the motor and application requirements. In order to absorb the energy generated during motor braking, an optional brake resistor (not supplied) can be connected to the appropriate J9 pins.

The motor supply connector also provides a grounding (earth) connection. This connection is used on-board for protection and shielding. It is electrically separated from the ACPM750 v3.4 electrical circuit.

CAUTION!
ALWAYS CONNECT THE EARTH TERMINAL INPUT OF THE MOTOR SUPPLY CONNECTOR TO A GOOD GROUNDING POTENTIAL!
IF THE EARTH PIN IS LEFT UNCONNECTED, DEADLY POTENTIALS MAY BE APPLIED TO THE ACPM750 AND TO THE OPERATOR!

The remaining two pins of the J9 motor supply are optionally used to connect an external braking resistor. The positive terminal of the braking resistor is internally connected to the positive DC-bus line of the ACPM750. The negative terminal of the braking resistor is connected to the braking IGBT provided on the ACPM750 v3.4. The external optional braking resistor must be chosen according to the application specific. For further details, see Chapter 2.3.5

The motor supply connector is a 6-pin 5.08-mm pitch removable screw-terminal connector. Its pin assignment is presented in Table 2.2.

Table 2.2. *J9 – Motor Supply Connector*

Pin	Name	Type	Function
1	**R**	**I**	Mono-phase: 90…220V_{AC} input line Three-phase: 60…120V_{AC} input line R
2	**S**	**I**	Mono-phase: 90…220V_{AC} input line Three-phase: 60…120V_{AC} input line S
3	**T**	**I**	Mono-phase: not used Three-phase: 60…120V_{AC} input line T
4	**EARTH**	**-**	Earth (ground) connection for protection & shielding
5	**BR+**	**O**	Brake resistor positive terminal
6	**BR-**	**O**	Brake resistor negative terminal

2.3. Power Stage Module

The ACPM750 v3.4 power stage module includes a 3-phase inverter, the protection circuits and the measurement circuits for the DC-bus voltage and the motor currents.

2.3.1. 3-phase Inverter Command

The 3-phase inverter (see Figure 2.2) uses IGBT transistors with switching frequency up to 24kHz.

The ACPM750 v3.4 MC-bus interface includes 6 PWM command inputs that accept 5-V TTL/ CMOS compatible signals named $\overline{PWM1}$ to $\overline{PWM6}$, through which the control unit can drive each transistor of the inverter.

All PWM commands are active low.

$\overline{PWM1}$, $\overline{PWM3}$, $\overline{PWM5}$ Drive the upper transistors.

$\overline{PWM2}$, $\overline{PWM4}$, $\overline{PWM6}$ Drive the lower transistors.

- $\overline{PWM1}$ & $\overline{PWM2}$ Drive phase A,
- $\overline{PWM3}$ & $\overline{PWM4}$ Drive phase B,
- $\overline{PWM5}$ & $\overline{PWM6}$ Drive phase C.

The ACPM750 v3.4 has on-board dead-time generator circuitry that automatically ads 0.8 μS dead time to the incoming PWM pulses. The control unit commands can have zero dead time for transistor commutation. Any extra dead time included in the PWM commands will be added to the ACPM750’s 0.8 μS.

Overlapping PWM pulses, which could lead to a shoot-through IGBT conduction, are automatically rejected by hardware. When such a situation occurs, the corresponding IGBT pair transistors are turned off.

The maximum conduction time for the upper IGBTs is limited to a duration of 50 mS. This is due to the dynamic bootstrap IGBT drivers used on board of the ACPM750 v3.4. However, the low-side IGBTs can be kept turned on indefinitely (static drive). If this time limit is reached, the corresponding upper IGBT is turned off, but no error is generated. Thus, the control program should avoid turning on an upper IGBT for more than 50 mS.

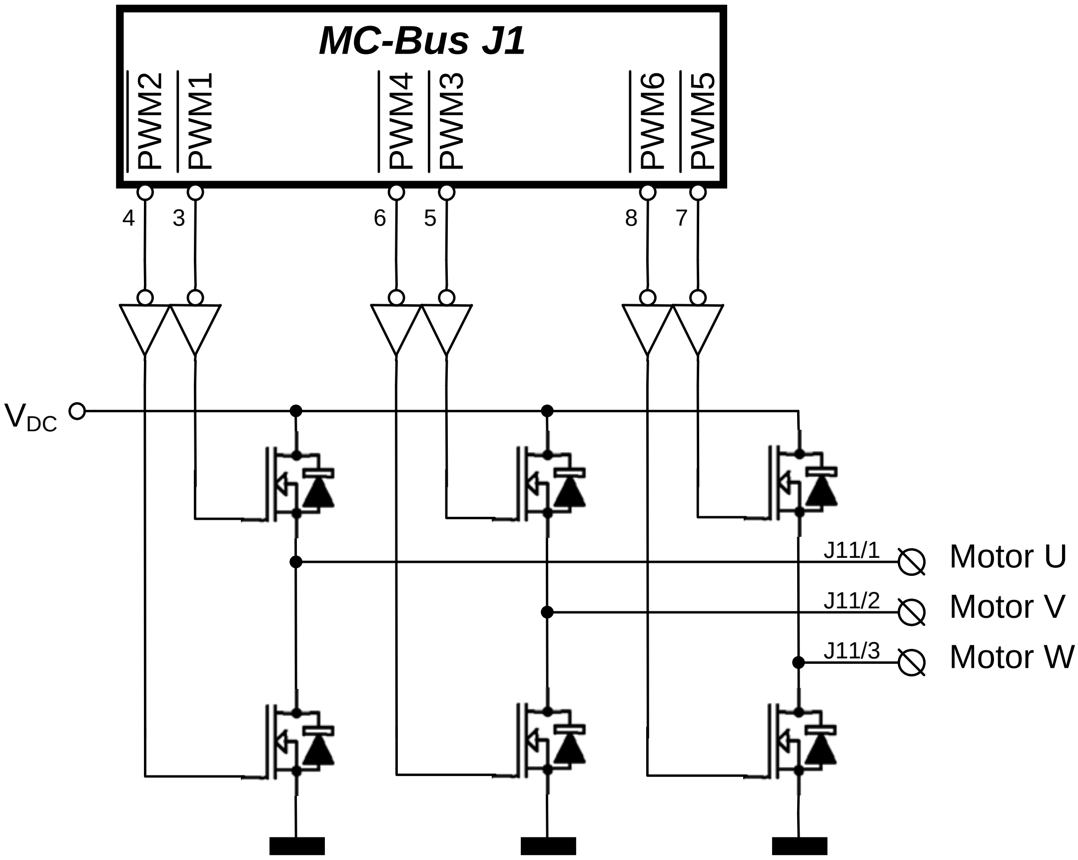


Figure 2.2. ***3-phase Inverter Control using PWM Command Inputs***

2.3.2. Protections. Error Signal

The ACPM750 v3.4 power stage includes protection circuits for several potentially harmful situations. These protection circuits are:

- Phase-to-phase short-circuit / over-current. This circuit monitors the current flow through the negative DC-bus bar. The protection is triggered if this current goes over 30 A for more than 200 μS.
- Phase-to-ground short-circuit / earth fault. This circuit monitors the current flow through the positive DC-bus bar. The protection is triggered if this current goes over 36 A for more than 100 μS.
- Over-temperature / overload. This circuit monitors the temperature of the IGBT power stage. The protection is triggered if the temperature increases over 100°C.

- DC-bus over-voltage / brake protection. This circuit monitors the DC-bus voltage. The protection is triggered when the voltage goes over 425 V.
- DC-bus under-voltage / in-rush current limiter. This circuit also monitors the DC-bus voltage. The protection is triggered whenever this voltage is below 80V_{DC} or below 80% of the rectified motor supply input voltage. This error signal is not only summed up in the error latch, but is also driving an on-board relay that switches a series resistor between the input rectifier and the DC-bus. More information about the in-rush current limiter can be found in Chapter **2.3.5**.
- Logic supply under-voltage / accidental logic supply shutdown. This circuit monitors the +5 V_{DC} logic supply voltage. The protection is triggered if this voltage goes under 4.5 V for more than 1 mS.

All these protections are summed up and used to set an error latch. This latch maintains the error state for an indefinite time, avoiding possible self-oscillating phenomena that could damage the power stage (repeated start-stop cycles).

The error set latch causes the red **LED2** to light, signals $\overline{\text{PDPINT}}$ from the MC-bus to go active low, and inhibits all PWM commands to the power stage, which turns off all six IGBTs.

Note: The brake IGBT is NOT protected against over-current / short-circuit. Also, the brake IGBT driving signal is NOT inhibited during error state. The intelligent control module should inactivate (pull high) the brake drive signal whenever a $\overline{\text{PDPINT}}$ is received.

CAUTION!
THE BRAKE TRANSISTOR IS NOT PROTECTED AGAINST SHORT-CIRCUITS. CHECK THE EXTERNAL BRAKE RESISTOR CONNECTIONS CAREFULLY, BEFORE ACTIVATING THE BRAKE TRANSISTOR!

In order to resume normal operation, the error latch must be reset to the default (normal operation) state. This is accomplished by pulling low signal $\overline{\text{ERRRST}}$. This signal has an on-board pull-up, which keeps it inactive high. The active-low pulse width must be longer than 2 µS. If the error, that has triggered the error latch, is still present, the $\overline{\text{ERRRST}}$ pulse will not clear the latch (i.e., the error latch “set” command is dominant over the “reset” command).

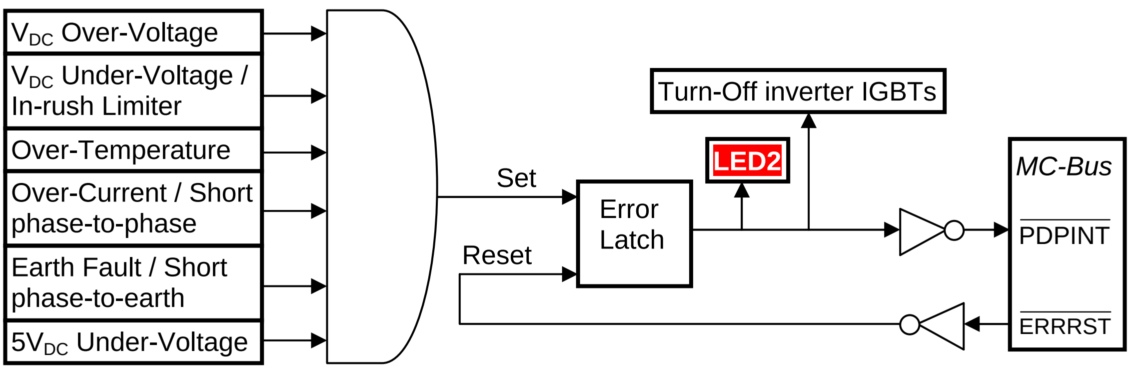


Figure 2.3. *Error latch*

2.3.3. Current Measurement Interface

The ACPM750 v3.4 measures the motor currents using isolated transducers placed in series with the outputs of the inverter (see below, Figure 2.4). The current measurement circuit has a gain factor of 0.5 V/A, which translates +/-5 A currents into +/-2.5 V voltages. These voltages are applied on the MC-bus analogue outputs IA and IB with a 2.5 V offset. Hence, positive currents are measured between 2.5 V and 5 V, and negative currents are measured between 0 and 2.5 V. The midpoint 2.5 V corresponds to a zero current.

Remark: A positive current is defined as flowing from the motor to the ACPM750. A negative current is defined as flowing from the ACPM750 to the motor.

Current I_A feedback is available at MC-Bus connector J1, pin 33 (signal I_A). Current I_B feedback is available at MC-Bus connector J1, pin34 (signal I_B).

Note: All analog measurements (including I_A and I_B feedbacks) require a valid V_{REF}HI and V_{REF}LO reference voltage to be applied on the MC-Bus pins by the intelligent controller module. This externally generated reference voltage is used on the ACPM750 v3.4 to create the +2.5 V offset that is added to the I_A and I_B feedbacks.

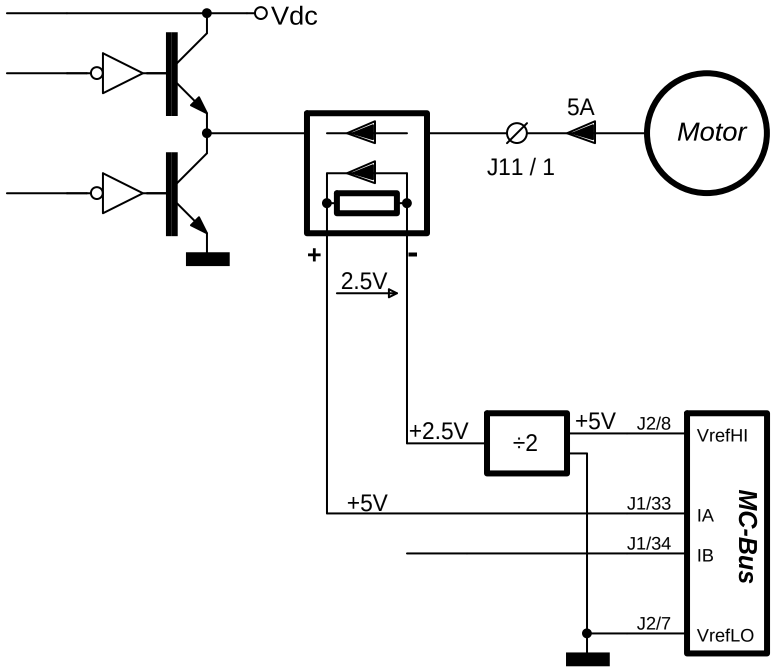


Figure 2.4. *Current Measurement*

2.3.3.1. Modifying the gain factor of the current measurement circuit

The ACPM750E current measurement circuits use two LEM sensors to read the motor currents in U and V phases. The main parameters of the LEM sensors are:

Type:	LEM HY10-P
Rated current I_{PN}:	±10A
Output Voltage V_{OUT}:	± 4 V (at ±10A)
Pass band	0 … 25 kHz
Accuracy	± 1 %

The phase-A current measurement circuit scheme is presented in **Figure 2.5**. Though the LEM sensors range may go up to 10A, most of the motor control applications in the ACPM750E power range do not require currents higher than 3.5 A, i.e. with an amplitude higher than 3 x 1.41 = 4.9 A. For this reason, the default gain factors of the current measurement circuit were set for a maximum current range of ±5 A. This current range corresponds to a ±2 V output range of the current sensors, which is translated into the 0÷5 V input range of the MC-Bus analog feedback.

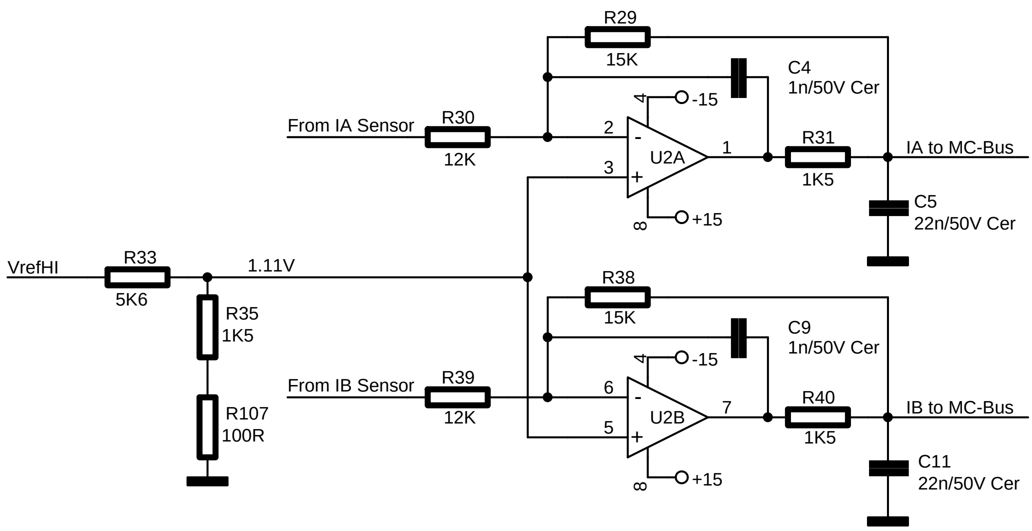


Figure 2.5. *The current measurement circuit*

According to **Figure 2.5**, the V_{AD} voltage applied to MC-Bus signals I_A and I_B is given by the relation:

$$V_{AD} = -I\frac{V_{OUT}}{I_{PN}}\frac{R29}{R30} + V_{REF}\frac{R35+R107}{R35+R107+R33}\left(1+\frac{R29}{R30}\right)$$

where:

- **I** ***is the motor current in A (considered positive when enters in the motor);***

- V_{OUT} / I_{PN} = ***0.4 V/A represents the current sensor constant***
- V_{REF} = 5V represents the external MC-Bus reference voltage $\mathbf{V_{REF}HI}$.

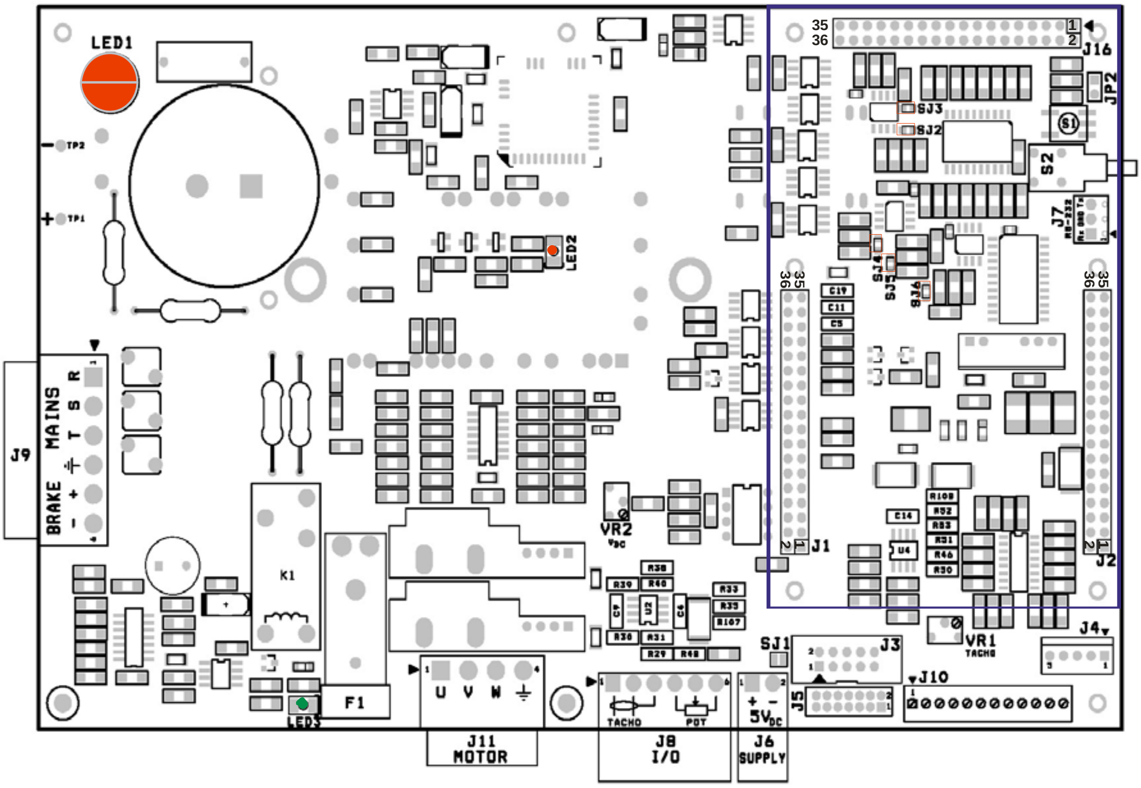


Figure 2.6. *Improving accuracy - the components to be modified*

If the motor current range in your application is much smaller than the ±5 A default range set in the ACPM750E, to improve the accuracy you may need to increase the gain of the measurement circuit. To do this, perform the following steps:

1. Compute the desired gain for the measurement circuit. For example, if your motor current range is up to ±1 A, you will need to increase the gain 5 times. The actual gain of the current measurement circuit is 0.5 V/A. So, you will need a 2.5 V/A gain.
2. Compute the new values for R29 and R30 from the relation:

   $$\text{Desired gain [V/A]} = 0.4 * R29 / R30$$

   Select the R30 value between 10 kΩ and 100 kΩ. Then compute the new R29 value. For example, if the desired gain is 2.5 V/A and R30 remains unchanged, R29 should be 86 KΩ.
3. Compute the new values for R35 and R33 with the relation:

   $$R33 = (R35+R107)\,(1 + 2 * R29 / R30)$$

Select the R35 value between 150 Ω and 2 kΩ. Then compute the new R33 value. For example, if R35 remains unchanged, R33 should be about 29 KΩ.

4. Remove the DSP board. Replace R29, R30, R33 and R35 (see **Figure 2.6**) with resistors having the new values computed above. Also replace R38 = R29 and R39 = R30 resistors which correspond to the phase-B current measurement circuit. Note that the reference voltage given by R33 and R35 + R107 is common to both current measurement circuits.

2.3.4. AC Supply / DC-bus Voltage Measurement

The ACPM750 v3.4 includes a AC supply / DC-bus voltage measurement feedback available on the MC-bus connector J1, pin31 (signal V_{DC}). The gain factor is 0.0117 V/V. Hence, DC-bus voltages between 0 … 425 V are translated into 0 … 5 V at the V_{DC} feedback output.

The measurement scheme provides low-pass filtering with a –3dB corner frequency of 75 Hz, in order to remove spurious switching noise generated by the on-board power stage.

2.3.4.1. Modifying the DC-bus voltage gain

The DC-bus voltage measurement circuit allows an easy change of the gain factor using the VR2 potentiometer. At one end of VR2, the gain factor is set to translate a 0 … 300 V DC-bus voltage range into 0-5 V input range of the ‘F240 A/D converter. At the other end of VR2, the gain factor is 1.5 times smaller, increasing the input range to 0 … 450 V. The default gain factor is set to 11.7 mV/V, i.e. 0 … 425 V DC-bus voltage translated into the 0 … 5 V ADC input range.

In order to adjust and measure the DC bus measurement circuit gain, perform the following steps:

1. If you have a brake resistor connected, remove it.
2. Power on the ACPM750 and turn on the brake transistor through the MC-bus (pull J1 pin 9 to ground, for example to J1 pin 29).
3. Measure the DC-bus voltage between the resistor pins brake (connector J14, pins 1 and 2).
4. Read the voltage between J1, pin 31 (signal V_{DC}), and analog ground (V_{REF}LO), for example at J1, pin 30.
5. Compute the ratio between the two measurements. This value is the actual gain factor, expressed in V/V.
6. Adjust the gain using the **VR2** potentiometer (see **Figure 2.1,** for details).
7. Repeat steps 4 to 6 until you get the desired gain factor.

2.3.5. Brake resistor & In-rush current limiting

In applications requiring higher dynamics, the DC-bus 400 V limit may be reached. In order to avoid protection triggering, a brake resistor can be used to speed up the voltage discharge. The time interval during which the brake resistor is connected to the DC-bus may be controlled through the brake transistor commanded by pin 9 of the MC-Bus connector J1.

When Pin 9 of MC-Bus J1 is active low, the brake transistor is turned on and the DC-bus voltage is applied on the brake resistor. The maximum current allowed through the brake transistor is 8 A.

The electrical schematic of the DC-bus circuit is presented in Figure **2.7**.

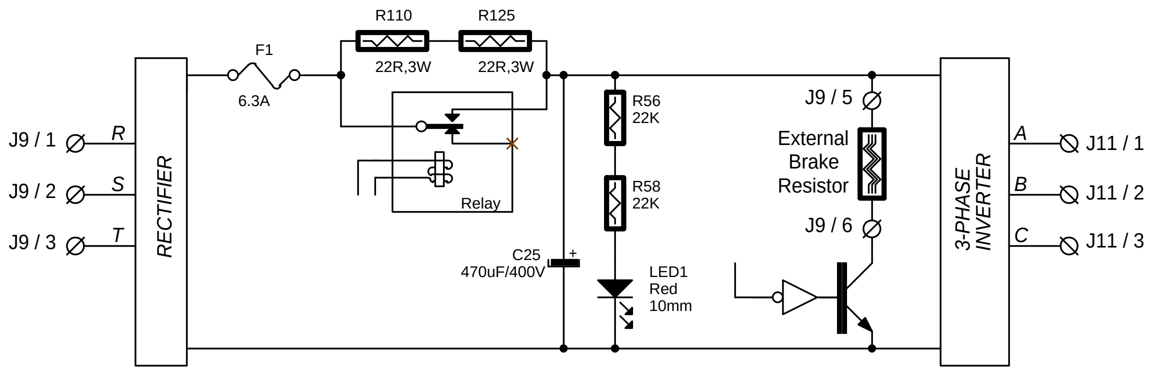


Figure 2.7. *DC-bus voltage measurement circuitry*

The relay is driven by the in-rush current limiter circuitry, and is short-circuited during the normal operation of the unit. The relay is released whenever the DC-bus voltage is below 80 V_{DC}. The relay is activated again only if the DC-bus voltage goes beyond 80% of the rectified motor supply input voltage. This functionality assures a smooth start-up regime for the input rectifier, when the DC-bus capacitor is discharged.

An error signal is generated while the relay is released. This avoids any inverter operations during the pre-charge period, when the DC-bus is in series with R110 and R125.

2.3.6. Tacho-generator feedback & Potentiometer reference

The ACPM750 v3.4 is provided with two analog inputs, to be used with an optional external tacho-generator and an external reference potentiometer. Both inputs are available at connector J8, with the pinout shown below.

Table 2.3. *J8 – Tacho & Potentiometer Connector: 6-pin 3.81mm removable screw terminal*

Pin	Name	Type	Function
1	**TACHO+**	**I**	**Tacho-generator positive input signal**
2	**TACHO-**	**-**	**Tacho-generator negative input signal; connected to GND on ACPM750 v3.4**
3	**SHIELD**	**-**	Shield for tacho signals; connected to GND on ACPM750 v3.4
4	**GND**	**-**	**Potentiometer (-); connected to GND on ACPM750 v3.4**
5	**REF**	**I**	Potentiometer wiper (cursor)
6	**+5V**	**O**	**Potentiometer (+)**

The tacho-generator input accepts bipolar voltages of ± 16 V from an external tacho-generator. The bipolar input voltage is translated into 0 … 5 V feedback available at pin 35 of MC-Bus connector J1. The signal is also smoothed with a 1^{st} order low-pass filter having a –3dB cut-off frequency of 200 Hz.

The potentiometer input is a 1:1 input (no attenuation, no gain), with added filtering (1^{st} order low-pass at 100 Hz). The external potentiometer is used as a voltage divider, and must be connected with the cursor on pin 5, and the other two terminals connected to pins 4 and 6 of J8. The analog voltage is available at pin 36 of MC-Bus connector J1. For proper operation, the potentiometer value should be between 1 kΩ and 5 kΩ.

2.3.6.1. Modifying the tacho-generator gain

Figure 2.8 presents the tacho-generator interface that translates the output voltage of a tachometer into the 0 … 5 V range of the MC-Bus signals. In order to cope with a large range of tachometer constants, this measurement circuit contains a potentiometer VR1 (see **Figure 2.1**) through which you can easily adjust the circuit gain factor. The following relationship gives the V_{AD} voltage available at MC-Bus:

$$V_{AD} = -V_{TACHO} \frac{R46}{R50} K \frac{VR1}{VR1 + R48} + 2.5V$$

Where V_{TACHO} is the tachometer output voltage, VR1 is the full range potentiometer value i.e. 1 KΩ and K represent the ratio between the cursor to ground resistance and VR1.

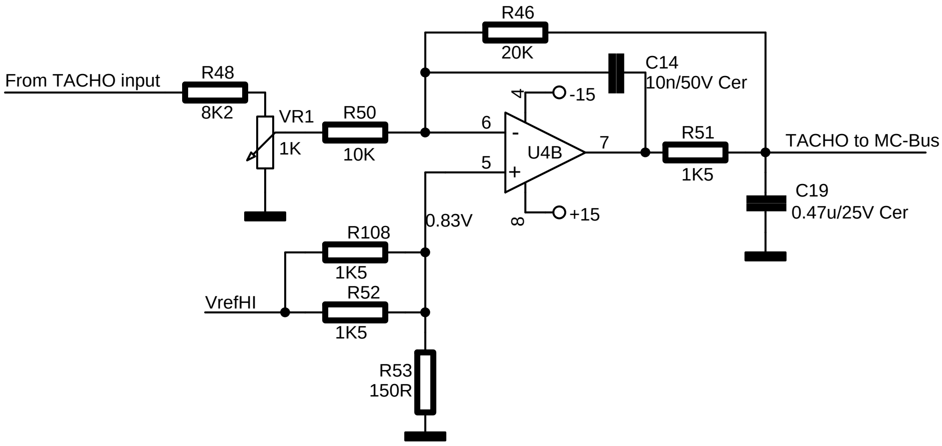


Figure 2.8. *Tacho-generator measurement circuit*

The ACPM750 is supplied with the VR1 cursor set for a default gain factor of 0.156 V/V, i.e. the 0…5 V MC-Bus signal range is obtained for a ±16 V tachometer output voltage. Using the potentiometer VR1, the gain factor may be increased up to 0.217 V/V, i.e. ±11.5 V full-scale input, or reduced (theoretically up to 0), allowing larger voltage ranges for tachometer output. If the maximum gain factor is still too large, it can be increased by reducing the R50 value. In this case, R52, R108 and R53 must also be modified to maintain the 2.5 V offset of the V_{AD} voltage. This condition imposes the following constraint in the selection of R50, R52, R108 and R53 resistors:

$$\frac{R52 + R53 + R108}{R52 \cdot R108 + R53 \cdot R52 + R53 \cdot R108}\left(1 + \frac{R46}{R50}\right) = 0.5$$

The tachometer measurement circuit includes a low-pass 1^{st} order passive filter with cutoff frequency 225 Hz.

2.3.7. J3, J4, J5, J10 – Encoder and Hall Sensors Connectors

The ACPM750 v3.4 is equipped with 4 connectors for the connection to an optional quadrature encoder and/or Hall sensors. Connector J2, J3 and J4 are appropriate for a direct connection to industry-standard feedback devices. J10 is a general-purpose screw-terminal type connector that allows arbitrary connections to any encoder and / or Hall sensors.

The ACPM750 encoder interface is equipped with differential RS-422 receivers for signals A, #A, B, #B, Z and #Z. This interface accepts both differential RS-422 signals, and single-ended TTL/CMOS compatible signals.

For single-ended encoders with TTL/CMOS interface, signals #A, #B and #Z of the ACPM750 must be left floating. In this configuration, all three encoder signals have on-board pull-ups of 1.5 KΩ at +5 V.

For encoders with differential RS-422 interface, it is possible to provide termination networks on each of the three differential pairs. The termination consist of three series R-C networks, connected across signal pairs A - #A, B - #B, Z - #Z. By default, the ACPM750 v3.4 is NOT equipped with the series resistors. To enable the termination, you will need three SMD resistors size 1206, rated at 0.25 W, with the value of 120 Ω ± 5%. The three resistors should be soldered on the pads provided on the PCB for **R133**, **R134** and **R135**. See **Figure 2.9** for details.

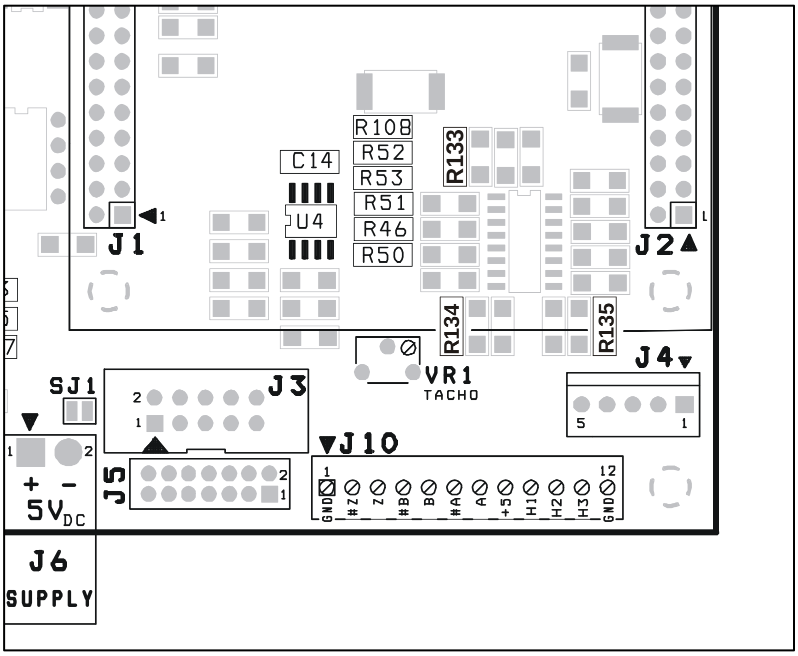


Figure 2.9. *Details for Encoder configuring*

***Important NOTE*:** When the ACPM750 v3.4 is equipped with the termination resistors, the operation of the single-ended TTL/CMOS encoders is corrupted. Always disconnect these terminations when using such encoders. The only configuration where termination resistors are recommended is for RS-422 encoders connected to the ACPM750 through a relatively long cable.

The quadrature encoder connector J3 can be configured from the **SJ1** solder joint (see **Figure 2.9**) to be compatible with API-Portescap A22 encoders or Hewlett Packard / Agilent HEDL65xx encoders. The **SJ1** solder joint must be:

- **ON** for HP HEDL65xx differential encoder type
- **OFF** for API-Portescap A22 single-ended encoder type (default)

The Hall sensors interface provided on the ACPM750 v3.4 includes 1.5 KΩ pull-up resistors at +5 V. This allows the connection of open-collector Hall sensors.

Tables 2.3.1 to 2.3.4 show the pinout for connectors J3, J4, J5 and J10. Also see Figures 2.1 and 2.9. for the location of these connectors.

Table 2.3.1. *J3 – Differential or Single-Ended Encoder Connector: 2 x 5-pin 2.54mm pitch header*

Pin	Name	Type	Function for Single-Ended TTL / CMOS (type API-Portescap A22)	Function for Differential RS-422 (type HP HEDL6xxx)
1	GND	-	Ground	Ground
2	+5V	O	+5 V_{DC} supply for encoder	+5 V_{DC} supply for encoder
3	n.c. or GND	-	Not connected (default)	Ground through solder-joint SJ1
4	+5V	O	+5 V_{DC} supply for encoder	+5 V_{DC} supply for encoder
5	#A or n.c.	I	Not connected	Complementary A signal
6	A	I	A signal	A signal
7	#B or n.c.	I	Not connected	Complementary B signal
8	B	I	B signal	B signal
9	#Z or n.c.	I	Not connected	Complementary Z (index) signal
10	Z	I	Z (index) signal	Z (index) signal

Table 2.3.2. *J4 – Single-Ended HP HEDS5xxx Encoder Connector: 5-pin 2.54mm Molex header*

Pin	Name	Type	Function for Single-Ended TTL/CMOS type HP HEDS 5xxx
1	**GND**	**-**	**Ground**
2	**Z**	**I**	Z (index) signal
3	**A**	**I**	**A signal**
4	**+5V**	**O**	+5V_{DC} supply for encoder
5	**B**	**I**	**B signal**

Table 2.3.3. *J5 – Differential Encoder & Hall Connector for API AC Brushless: 2x7-pin 2.0 mm pitch Hirose header*

Pin	Name	Type	Function
1	**A**	**I**	**A signal**
2	**#A**	**I**	**Complementary A signal**
3	**B**	**I**	**B signal**
4	**#B**	**I**	**Complementary B signal**
5	**Z**	**I**	**Z (index) signal**
6	**#Z**	**I**	**Complementary Z (index) signal**
7		**n.c.**	**Not connected on ACPM750 v3.4**
8	**HALL 1**	**I**	**Hall sensor 1**
9	**HALL 2**	**I**	**Hall sensor 2**
10	**HALL 3**	**I**	**Hall sensor 3**
11	**GND**	**-**	**Ground**
12	**+5 V**	**O**	**+5 V_{DC} supply for Hall sensors**
13	**+5 V**	**O**	**+5 V_{DC} supply for encoder**
14	**GND**	**-**	**Ground**

Table 2.3.4. *J10 – Differential or Single-Ended Encoder & Hall Connector: 12-way 2.54 mm pitch screw terminals*

Pin	Name	Type	Function
1	**GND**	**-**	**Ground**
2	**#Z**	**I**	**Complementary Z (index) signal**
3	**Z**	**I**	**Z (index) signal**
4	**#B**	**I**	**Complementary B signal**
5	**B**	**I**	**B signal**
6	**#A**	**I**	**Complementary A signal**
7	**A**	**I**	**A signal**
8	**+5 V**	**O**	**+5 V_{DC} supply for encoder and Hall**
9	**HALL 1**	**I**	**Hall sensor 1**
10	**HALL 2**	**I**	**Hall sensor 2**
11	**HALL 3**	**I**	**Hall sensor 3**
12	**GND**	**-**	**Ground**

2.4. Communication

2.4.1. J7 – RS-232 optional connector

The ACPM750 v3.4 power module is to be used together with an MC-Bus compatible intelligent control module. Most of these control units manufactured by Technosoft already have an RS-232 standard Sub-D 9 connector. However, to allow the development of new control modules, the ACPM750 v3.4 is provided with an optional connector J7 that provides access to the RS-232 signals. This connector should NOT be used normally, since its functionality is replaced by the Sub-D 9 RS-232 connector provided on the intelligent module.

The optional J7 connector is a screw-terminal 2.54-mm pitch 3-pin connector. Its pinout is shown in Table 2.4.1

Table 2.4.1 *J7 – Optional RS-232 Connector: 3-pin 2.54mm pitch screw-terminal connector*

Pin	Name	Type	Function
1	RxD	I	Data Reception
2	GND		Ground
3	TxD	O	Data Transmission

A serial cable between the ACPM750 v3.4 power module and a PC must have the connections as described in Table **2.4.2**.

Table 2.4.2. *RS-232 serial cable connections*

	Pin Assignments		
Signal Name	**PC**		**ACPM750 v3.4**
	DB25 Female	**DB9 Female**	**J7 connector**
Receive Data	2	3	1
Signal ground	7	5	2
Transmit Data	3	2	3

2.5. Control Unit Interface (MC-Bus)

2.5.1. J1, J2 – MC-Bus Connectors

The ACPM750 v3.4 power module receives the PWM command signals and sends the feedback and status signals to the control unit through the two 2 x 18-pin 0.1" pitch MC-Bus connectors J1 and J2. The MC-Bus is a standard interface (using 5.5 V TTL level signals) that permits connecting different Technosoft control and measurement modules with a range of power modules including ACPM750 v3.4. Tables **2.5.1** and **2.5.2** present the ACPM750 v3.4 pin assignment on the MC-Bus connectors. The ACPM750 v3.4 is delivered with socket type (female) connectors on the MC-Bus that accept standard headers mounted on the control unit, which is placed above the ACPM750 v3.4.

Table 2.5.1 *J1 – MC-bus connector*

Pin	Name	Type	Description
1		n.c.	Not connected on the ACPM750 v3.4
2			
3	$\overline{\text{PWM1}}$	I [1]	CU [2] output. Active low command for the upper transistor, A-phase leg
4	$\overline{\text{PWM2}}$	I	CU output. Active low command for the lower transistor, A-phase leg
5	$\overline{\text{PWM3}}$	I	CU output. Active low command for the upper transistor, B-phase leg
6	$\overline{\text{PWM4}}$	I	CU output. Active low command for the lower transistor, B-phase leg
7	$\overline{\text{PWM5}}$	I	CU output. Active low command for the upper transistor, C-phase leg
8	$\overline{\text{PWM6}}$	I	CU output. Active low command for the lower transistor, C-phase leg
9	$\overline{\text{BRAKE}}$	I	CU output. Active low command for brake transistor.
10	$\overline{\text{ERRRST}}$	I	CU output. Active low command for error latch reset.
11		n.c.	Not connected on the ACPM750 v3.4
12			
13			
14			
15			
16			
17	ENC-A	O [3]	CU input. Encoder signal A from J3, J4, J5 or J10

[1] I – input in ACPM750 v3.4, output from control unit
[2] CU – control unit connected through the MC-bus with ACPM750 v3.4
[3] O – output from ACPM750 v3.4, input in CU

18	ENC-B	O	CU input. Encoder signal B from J3, J4, J5 or J10
19	ENC-Z	O	CU input. Encoder signal Z (index) from J3, J4, J5 or J10
20		n.c.	Not connected on the ACPM750 v3.4
21	$\overline{\text{PDPINT}}$	O	CU input. Power stage error signal, driven by protection circuitry. Active low, open-collector signal (requires pull-up to +5 V)
22		n.c.	Not connected on the ACPM750 v3.4
23			
24			
25	+5 V_{DC}	O	+5 V_{DC} from J6 connector
26	GND	-	Ground terminal. All digital signals are referenced to this signal
27	GND		
28	GND		
29	GND		
30	V_{REF}LO	-	Analog Ground. Used as reference for all analog signals. Must be connected to GND on CU.
31	V_{DC}	O	CU analog input. DC-bus voltage measurement (0.0117 V/V)
32		n.c.	Not connected on the ACPM750 v3.4
33	I_A	O	CU analog input. Phase A current measurement (0.5 A/V + 2.5 V)
34	I_B	O	CU analog input. Phase B current measurement (0.5 A/V + 2.5 V)
35	TACHO	O	CU analog input. Tacho-generator feedback from J8 (0.156 V/V + 2.5 V)
36	REF	O	CU analog input. Potentiometer reference from J8 (1.0 V/V)

Table 2.5.2 *J2 – MC-bus connector*

Pin	Name	Type	Description
1		n.c.	Not connected on the ACPM750 v3.4
2			
3			
4			
5			
6			
7	V_{REF}LO	-	Analog Ground. Used as reference for all analog signals. Must be connected to GND on CU.
8	V_{REF}HI	I	Analogue reference. CU must provide +5 V on this pin. Half of this value is used to shift analog bipolar signals. Typical expected value is +5 V, allowed range is +4.75…5.25 V.Current drawn by ACPM750 v3.4 is under 8 mA
9	GND	-	Ground terminal. All digital signals are referenced to this signal

10	GND		
11	HALL 1	O	CU input. HALL 1 signal from J5 or J10
12		n.c.	Not connected on the ACPM750 v3.4
13	HALL 2	O	CU input. HALL 2 signal from J5 or J10
14	HALL 3	O	CU input. HALL 3 signal from J5 or J10
15	GND	-	Ground terminal. All digital signals are referenced to this signal
16	GND		
17	Rx232	O	CU RS-232 input, tied directly to J7 pin 1
18	Tx232	I	CU RS-232 output, tied directly to J7 pin 3
19		n.c.	Not connected on the ACPM750 v3.4
20			
21	+5 V_{DC}	O	+5 V_{DC} from J6 connector
22			
23	$\overline{\text{RESET}}$	O	CU input. Connected to push-button. Strap to GND when pushed. Typical usage: Reset.
24		n.c.	Not connected on the ACPM750 v3.4
25			
26			
27			
28			
29			
30			
31	In	O	CU input. Provides JP2 position: JP2 = on -> logic 1; JP2 = off -> logic 0. Typical usage: Monitor/User (JP2=on for Monitor, JP2=off for User) ***or*** AutoRun (JP2=off for AutoRun).
32		n.c.	Not connected on the ACPM750 v3.4
33			
34			
35			
36			

2.6. Jumpers and Solder-joints

The ACPM750 v3.4 power module provides one jumper JP2 (see **Figure 2.1**) whose presence determines the level of the digital input “In” connected to the MC-Bus:

- JP2 = on: signal “In” is high (logic 1)
- JP2 = off: signal “In” is pulled low (logic 0)

Signal “In” from MC-Bus pin 31 can be used by the intelligent control module either as an AUTORUN input (for MotionChip™ based modules), or as Monitor / User start-up switch. Please consult the intelligent control module User Manual for further details.

The ACPM750 v3.4 power module provides 5 solder-joints SJ2, SJ3, SJ4, SJ5 and SJ6 (see **Figure 2.1**) which configure the voltage range for the following analog outputs:

- ACPM_Tacho
- ACPM_Ref
- ACPM_VDC
- ACPM_I_V
- ACPM_I_U

Solder-joint	Analog output	Connector / pin	State	Output Voltage Range	Compatible board(s)
SJ2	ACPM_Tacho	J16 / 31	ON (STRAPPED)	0 … 3.0 V	MSK28335 / MSK2812
			OFF (OPEN)	0 … 3.3 V	MSK2407
SJ3	ACPM_Ref	J16 / 32	ON (STRAPPED)	0 … 3.0 V	MSK28335 / MSK2812
			OFF (OPEN)	0 … 3.3 V	MSK2407
SJ4	ACPM_VDC	J16 / 33	ON (STRAPPED)	0 … 3.0 V	MSK28335 / MSK2812
			OFF (OPEN)	0 … 3.3 V	MSK2407
SJ5	ACPM_I_V	J16 / 34	ON (STRAPPED)	0 … 3.0 V	MSK28335 / MSK2812
			OFF (OPEN)	0 … 3.3 V	MSK2407
SJ6	ACPM_I_U	J16 / 35	ON (STRAPPED)	0 … 3.0 V	MSK28335 / MSK2812
			OFF (OPEN)	0 … 3.3 V	MSK2407

CAUTION!
DO NOT CONNECT A DSP BOARD WITH 3.0V ANALOG INPUTS (MSK28335 / MSK2812) WHEN THE ACPM750 HAS THE ANALOG OUTPUTS CONFIGURED FOR 3.3V. YOU CAN DAMAGE THE DSP BOARD.

2.7. S2 – Reset Pushbutton

The ACPM750 v3.4 power module is equipped with a push-button S2 (see **Figure 2.1**), which is connected to the MC-Bus pin 23 of J2, signal $\overline{\text{RESET}}$. This button, when pushed, pulls the MC-Bus reset line to ground, which generates a reset of the intelligent controller module. For further details about reset operation, please consult the User Manual of the intelligent module.

2.8. LED1, LED2, LED3

The ACPM750 v3.4 provides visual signalling through 3 light-emitting diodes (LEDs). The location of these LEDs is shown in **Figure 2.1**. Each LED signals a specific operation, as follows:

- **LED1.** High voltage presence: is a 10-mm diameter (large) red LED, located close to the corner of the ACPM750 v3.4. It is connected across the internal DC-bus, and lights whenever the DC-bus voltage is over ~ 50 V. See **Figure 2.7** for a schematic representation of the LED1 connection.

CAUTION!
DO NOT TOUCH THE ACPM750 WHEN THE LARGE RED LED IS LIT. THE ACPM750 AREA BELOW THE TRANSPARENT COVER CONTAINS HIGH VOLTAGES THAT ARE DANGEROUS FOR YOUR LIFE.

- **LED2.** Error: is an SMD red LED located inside the high-voltage area of the ACPM750 v3.4. It is connected to the error latch output, and lights whenever the error latch is activated. Also see **Figure 2.3** for details. It can also be thought of as a visual representation of the $\overline{\text{PDPINT}}$ signal: when LED2 is lighting, the MC-Bus $\overline{\text{PDPINT}}$ error signal is active low.
- **LED3.** Normal Operation: is an SMD green LED located near the in-rush relay. This LED is lit after about 1 second from the connection of the high-voltage power supply, after the in-rush current-limiting resistance has been short-circuited. The lighting of this LED shows that normal operation of the ACPM750 is enabled.

2.9. Fuse F1

The ACPM750 v3.4 is provided with a 6.3 A fuse, type 20 mm x 5 mm slow fusing. The location of fuse F1 can be found in **Figure 2.6**. The fuse is series connected with the DC-bus (see **Figure 2.7** for details), and offers protection against hazardous defects of the ACPM750. If you need to replace F1, use only slow fusing models (standard, not fast) rated at 6.3 A.]

2.10. Installation, power-up and power-down procedures

To power-up the ACPM750 v3.4 together with an intelligent control module, perform the following operation sequence:

1. Plug the intelligent module onto the ACPM750:
   - Use MC-Bus connectors J1 and J2 for IMMC / MCSK boards
   - Use J16 connector for MSK28335 / MSK2812 / MSK2407. Check if the power module has the correct solder-joint configuration for DSP module. For details see paragraph 2.6 Jumpers and solder-joints.

CAUTION!
DO NOT CONNECT A BOARD WITH 3.0V ANALOG INPUTS (MSK28335 / MSK2812) WHEN THE ACPM750 HAS THE ANALOG OUTPUTS CONFIGURED FOR 3.3V. YOU CAN DAMAGE THE DSP BOARD.

2. Connect the RS-232 cable to the intelligent module
3. Turn on the +5 V_{DC} supply
4. Test if the communication with the DSP board works.
5. Download your program
6. Turn on the AC motor supply. The HV (high voltage) large red LED1 should light on, signaling the presence of high voltage on the DC-bus. After a short time, the normal operation green LED3 should also light on.

   Note: After power-on or reset of the DSP board, all the PWM outputs are in High-Z and the $\overline{\text{BRAKE}}$ and $\overline{\text{ERRRST}}$ pins are set as inputs. In this initial state all these signals are read as logic 1, which turns off all 6 inverter IGBTs and the brake transistor, and activates the error detection and signaling circuit. This initial state allows you to turn on the AC motor power supply, without needing to execute a prior initialization procedure.

7. Check the status of the ACPM750 red error LED2. If the led is lit, then an error condition has occurred during power-up. This situation is normal upon power-up, due to the in-rush current limiting protection and under-voltage protection. The error condition remains latched in the ACPM750 error latch, until it is reset with a low pulse generated on the $\overline{\text{ERRRST}}$ MC-Bus pin. The pulse duration must be of minimum 2μs. After the error condition is reset, the PWM commands can be applied to the inverter. This initial pulse could be included in your application initialization routine.
8. Start executing your application. The initialization procedure of your program should:
   - Inhibit all PWM commands to the inverter by setting all six PWM outputs high;
   - Activate the ACPM750 error detection and signaling circuit by setting the $\overline{\text{ERRRST}}$ signal high (logic 1 output);
   - Inhibit the brake transistor command (if brake resistor is connected) by setting the $\overline{\text{BRAKE}}$ pin high (logic 1 output);

   Your program can detect the error condition and can reset the error latch automatically. The error latch that lights error LED2 is also driving MC-Bus signal $\overline{\text{PDPINT}}$. Enable the PDPINT interrupt through software and, if an error occurs, set all PWM outputs in the interrupt service routine inactive (high), generate a low pulse on $\overline{\text{ERRRST}}$ for minimum 2 μs, then reactivate the PWM outputs.

   To power down the ACPM750 + intelligent control module, the following operation sequence must be performed:

9. Turn off the AC motor power supply.
10. Wait until the HV (high-voltage) big red led LED1 is off. This will take approximately 30 seconds, time required for the DC-bus capacitor to discharge.
11. Turn off the +5 V_{DC} logic supply.

Appendices

Appendix A. ACPM750 v3.4 Electrical Specifications

Parameter	Conditions	Min.	Typ.	Max.	Units
AC Motor Input Supply					
Voltage	Single phase ("T" not used)	90	220	280	V_{RMS}
	Three phase (neutral not used); Phase voltage	60	120	160	V_{RMS}
Frequency		40	50,60	440	Hz
Input current	Nominal output power		6.2		A_{RMS}
	Initial in-rush capacitor charging			10	A_{PEAK}
Internal DC-bus voltage				400	V
DC Logic Input Supply					
Voltage		4.75	5	5.25	V_{DC}
Input current	Required by ACPM750 v3.4 only. For total rating, add the control unit current		1.0	1.2	A
Output Power					
Voltage	set by external PWM control; measured between two phases	0		230	V_{RMS}
Nominal Motor Power	$V_{in} = 220\ V_{AC}$, $f_{pwm} = 20$ kHz, $V_{out} = 161\ V_{RMS}$, $f_{out} = 50$ Hz, PF = 0.77, $T_A = 40°C$			750	W
Overload Motor Power	Same conditions as above, 60-second duration			1200	W
Nominal Motor Current	$V_{in} = 220\ V_{AC}$, $f_{pwm} = 20$ kHz, $V_{ou} = 161\ V_{RMS}$, $f_{out} = 50$ Hz, PF =0.77, $T_A = 40°C$			3.5	A_{RMS}
Overload Motor Current	Same conditions as above, 60-second duration			6	A_{RMS}
PWM frequency		0.1	20	24	kHz
Inverter output dead band	Measured at inverter outputs, using PWM commands with dead time of 0 μs, $T_A = 25ºC$		0.2		μs
Brake Output Current				6	A_{RMS}
Protections					
Output current trip level	Phase-to-phase, $T_C = 25ºC$		30		A_{PEAK}
Output current trip duration	Outputs shorted, $T_C = 25ºC$		200		μS
Earth Fault current trip level	Phase-to-earth, $T_C = 25ºC$		36		A_{PEAK}

Parameter	Conditions	Min.	Typ.	Max.	Units
Over-temperature trip level	IGBT module temperature	90	100	120	ºC
DC-bus over-voltage level		410	425	440	V
DC-bus under-voltage level	In-rush limiter relay threshold		70	80	V
Inputs from MC-BUS – J1, J2 (6 PWM, Brake, ErrRst)					
PWM dead band command	Measured at MC-BUS pins	0			μs
High level input voltage	TTL compatible	2			V
Low level input voltage	TTL compatible			0.8	V
High level input current	Compatible with open-collector outputs	0		0	mA
Low level input current				6	mA
Error Reset pulse width	Active low	2			μs
Brake minimum pulse width	Active low	4			μs
Analog Outputs to MC-BUS – J1, J2					
I_A, I_B feedback gain			0.5		V / A
I_A, I_B feedback offset	$V_{REF}HI = 5\ V_{DC}$	2.375	2.5	2.625	V
I_A, I_B feedback bandwidth	2nd order, -3dB		5		KHz
V_{DC} feedback gain	Adjustable by VR2		11.7		mV / V
V_{DC} feedback offset			0		V
V_{DC} feedback bandwidth	2nd order, -3dB		75		Hz
TACHO gain	Adjustable by VR1		0.156		V / V
TACHO offset	$V_{REF}HI = 5\ V_{DC}$	2.375	2.5	2.625	V
TACHO bandwidth	1st order, -3dB		200		Hz
REF potentiometer gain			1		V / V
REF potentiometer offset			0		V
REF potentiometer bandwidth	1st order, -3dB		100		Hz
REF potentiometer	Recommended value	1		5	KΩ
Digital Outputs to MC-BUS – J1, J2 (PDPINT, IN, Reset)					
Low level output voltage	PDPINT (open-collector), I_{OL}<10mA		0.3	0.4	V
	IN (4.7 KΩ pull-down), I_{OL} < 0.15 mA, JP2 = off			0.8	V
	RESET (direct link to GND), S2 pressed		0		V
High level output voltage	PDPINT open-collector, I_{OH} = 0		5	7	V
	IN (direct link to +5 V)		5		V
	RESET (4.7 KΩ pull-up), I_{OH} < 0.6 mA, S2 released	2			V

Parameter	Conditions	Min.	Typ.	Max.	Units
Hall Inputs					
High level input current	1.5 KΩ Pull-up resistor to +5 V	0		0	mA
High level input voltage		2			V
Low level input current	1.5 KΩ Pull-up resistor to +5 V			3.5	mA
Low level input voltage				0.8	V
Encoder Inputs					
High level input current	1.5 kΩ pull-ups to +5 V on A, B, Z; Single-ended operation (#A, #B, #Z floating)	0		0	mA
High level input voltage		0.9	0.95	1.0	V
Low level input current			3.5		mA
Low level input voltage		0.8	0.85	0.9	V
Differential inputs		Conform to RS-422			
RS-422 termination network	Resistors NOT mounted by default	120 Ω series 10 nF			
System Environment					
Ambient Operating Temp.	90% RH max. (non-condensing)	0		40	ºC

Appendix B. MC-Bus Pin Correspondence with IMMC240 v3.0 and MCSK v1.0

J1 – MC-bus connector

Pin	ACPM750 v3.4 signal	IMMC240 signal	MCSK signal
1	n.c.	n.c.	n.c.
2	n.c.	n.c.	n.c.
3	$\overline{\text{PWM1}}$	PWM1	$\overline{\text{PWM1}}$
4	$\overline{\text{PWM2}}$	PWM2	$\overline{\text{PWM2}}$
5	$\overline{\text{PWM3}}$	PWM3	$\overline{\text{PWM3}}$
6	$\overline{\text{PWM4}}$	PWM4	$\overline{\text{PWM4}}$
7	$\overline{\text{PWM5}}$	PWM5	$\overline{\text{PWM5}}$
8	$\overline{\text{PWM6}}$	PWM6	$\overline{\text{PWM6}}$
9	$\overline{\text{BRAKE}}$	CMP7 / IOPB0	IO#4/ $\overline{\text{BRAKE}}$
10	$\overline{\text{ERRRST}}$	CMP8 / IOPB1	IO#5
11	n.c.	CMP9 / IOPB2	IO#6
12	n.c.	T1CMP / IOPB3	IO#7
13	n.c.	T2CMP / IOPB4	IO#8
14	n.c.	T3CMP / IOPB5	IO#9
15	n.c.	TMRDIR / IOPB6	IO#10/DIR
16	n.c.	TMRCLK / IOPB7	IO#11/PULSE
17	ENC-A	QEP1 / IOPC4	IO#16/ENCA
18	ENC-B	QEP2 / IOPC5	IO#17/ENCB
19	ENC-Z	CAP3 / IOPC6	IO#18/CAPI/HALL1
20	n.c.	CAP4 / IOPC7	IO#19/CAPH/DIR
21	$\overline{\text{PDPINT}}$	$\overline{\text{PDPINT}}$	$\overline{\text{PDPINT}}$
22	n.c.	XINT2 / IO	LSP
23	n.c.	SCIRXD / IO	SCIRXD
24	n.c.	SCITXD / IO	SCITXD
25	+5 V_{DC}	+5 V_{DC}	+5 V_{DC}
26	GND	DGND	DGND
27	GND	DGND	DGND
28	GND	DGND	DGND
29	GND	DGND	DGND
30	V_{REF}LO	VrefLO	V_{REF}LO
31	V_{DC}	ADCIN5	TEMP1/TQLIM/ADCIN5

32	n.c.	ADCIN13	n.c.
33	I_A	ADCIN6	FEEDBACK/ADCIN6
34	I_B	ADCIN14	REFERENCE/ADCIN14
35	TACHO	ADCIN7	ADCIN7
36	REF	ADCIN15	TEMP2/TQFFW/ADCIN15

J2 – MC-bus connector

Pin	ACPM750 v3.4 signal	IMMC240 signal	MCSK signal
1	n.c.	ADCIN2	CFG/ADCIN2
2	n.c.	ADCIN10	ADCIN10
3	n.c.	ADCIN3	VDC/ADCIN3
4	n.c.	ADCIN11	IB/ADCIN11
5	n.c.	ADCIN4	IA/ADCIN4
6	n.c.	ADCIN12	IC/ADCIN12
7	V_{REF}LO	V_{REF}LO	V_{REF}LO
8	V_{REF}HI	V_{REF}HI	V_{REF}HI
9	GND	DGND	DGND
10	GND	DGND	DGND
11	HALL 1	IOPA0	IO#0/HALL1
12	n.c.	IOPA3	IO#3/TXEN485
13	HALL 2	IOPA1	IO#1/HALL2
14	HALL 3	IOPA2	IO#2/HALL3
15	GND	DGND	DGND
16	GND	DGND	DGND
17	Rx232	RX	RxD
18	Tx232	TX	TxD
19	n.c.	n.c.	n.c.
20	n.c.	n.c.	n.c.
21	+5 V_{DC}	+5 V_{DC}	+5 V_{DC}
22	+5 V_{DC}	+5 V_{DC}	+5 V_{DC}
23	$\overline{\text{RESET}}$	PORESET	$\overline{\text{PORESET}}$
24	n.c.	- reserved -	V_{EE}
25	n.c.	- reserved -	n.c.
26	n.c.	- reserved -	n.c.
27	n.c.	SPISIMO / IO	SPISIMO
28	n.c.	SPISOMI / IO	SPISOMI

29	n.c.	SPICLK / IO	SPICLK
30	n.c.	SPISTE / IO	SPISTE
31	In	ADCSOC / IOPC0	$\overline{\text{AUTORUN}}$
32	n.c.	CLKOUT / IOPC1	CLKOUT/IO#13
33	n.c.	XF / IOPC2	$\overline{\text{MCRDY}}$
34	n.c.	BIO / IOPC3	$\overline{\text{INT2HOST}}$
35	n.c.	XINT3 / IO	LSN
36	n.c.	NMI	ENABLE

Appendix C. MC-Bus Pin Correspondence with MSK243 v1.1

J1 – MC-bus connector

Pin	ACPM750 v3.4 signal	MSK243 signal
1	n.c.	n.c.
2	n.c.	n.c.
3	$\overline{\text{PWM1}}$	PWM1
4	$\overline{\text{PWM2}}$	PWM2
5	$\overline{\text{PWM3}}$	PWM3
6	$\overline{\text{PWM4}}$	PWM4
7	$\overline{\text{PWM5}}$	PWM5
8	$\overline{\text{PWM6}}$	PWM6
9	$\overline{\text{BRAKE}}$	IOPD2
10	$\overline{\text{ERRRST}}$	IOPD3
11	n.c.	IOPD4
12	n.c.	T1CMP / IOPB4
13	n.c.	T2CMP / IOPB5
14	n.c.	IOPD5
15	n.c.	TMRDIR / IOPB6
16	n.c.	TMRCLK / IOPB7
17	ENC-A	QEP1 / IOPA3
18	ENC-B	QEP2 / IOPA4
19	ENC-Z	CAP3 / IOPA5
20	n.c.	IOPD6
21	$\overline{\text{PDPINT}}$	$\overline{\text{PDPINT}}$
22	n.c.	XINT2 / IOPD1
23	n.c.	SCIRXD / IOPA1
24	n.c.	SCITXD / IOPA0
25	+5V_{DC}	+5V_{DC}
26	GND	DGND
27	GND	DGND
28	GND	DGND
29	GND	DGND

J2 – MC-bus connector

Pin	ACPM750 v3.4 signal	MSK243 signal
1	n.c.	n.c.
2	n.c.	n.c.
3	n.c.	ADCIN4
4	n.c.	ADCIN5
5	n.c.	ADCIN6
6	n.c.	ADCIN7
7	V_{REF}LO	VrefLO
8	V_{REF}HI	VrefHI
9	GND	DGND
10	GND	DGND
11	HALL 1	n.c. (see remark)
12	n.c.	n.c.
13	HALL 2	n.c. (see remark)
14	HALL 3	n.c. (see remark)
15	GND	DGND
16	GND	DGND
17	Rx232	RxD
18	Tx232	TxD
19	n.c.	CAN_HI
20	n.c.	CAN_VCC
21	+5 V_{DC}	+5 V_{DC}
22	+5 V_{DC}	+5 V_{DC}
23	$\overline{\text{RESET}}$	$\overline{\text{PORESET}}$
24	n.c.	n.c.
25	n.c.	CAN_LO
26	n.c.	CAN_GND
27	n.c.	SPISIMO / IOPC2
28	n.c.	SPISOMI / IOPC3
29	n.c.	SPICLK / IOPC4

30	V_{REF}LO	VrefLO
31	V_{DC}	- n.c. - (ADCIN4)
32	n.c.	n.c.
33	I_A	ADCIN0
34	I_B	ADCIN1
35	TACHO	ADCIN2
36	REF	ADCIN3

30	n.c.	SPISTE / IOPC5
31	In	IOPD7
32	n.c.	CLKOUT / IOPD0
33	n.c.	XF / IOPC0
34	n.c.	BIO / IOPC1
35	n.c.	XINT1 / IOPA2
36	n.c.	$\overline{\text{NMI}}$

Remark: When MSK243 v1.1 is delivered together with an ACPM750 v3.4, the MSK243 board includes an adapter. The adapter links the following MC-Bus signals:

a) J2 / pin 11 with J1 / pin 11

b) J2 / pin 13 with J1 / pin14

c) J2 / pin 14 with J1 / pin 20.

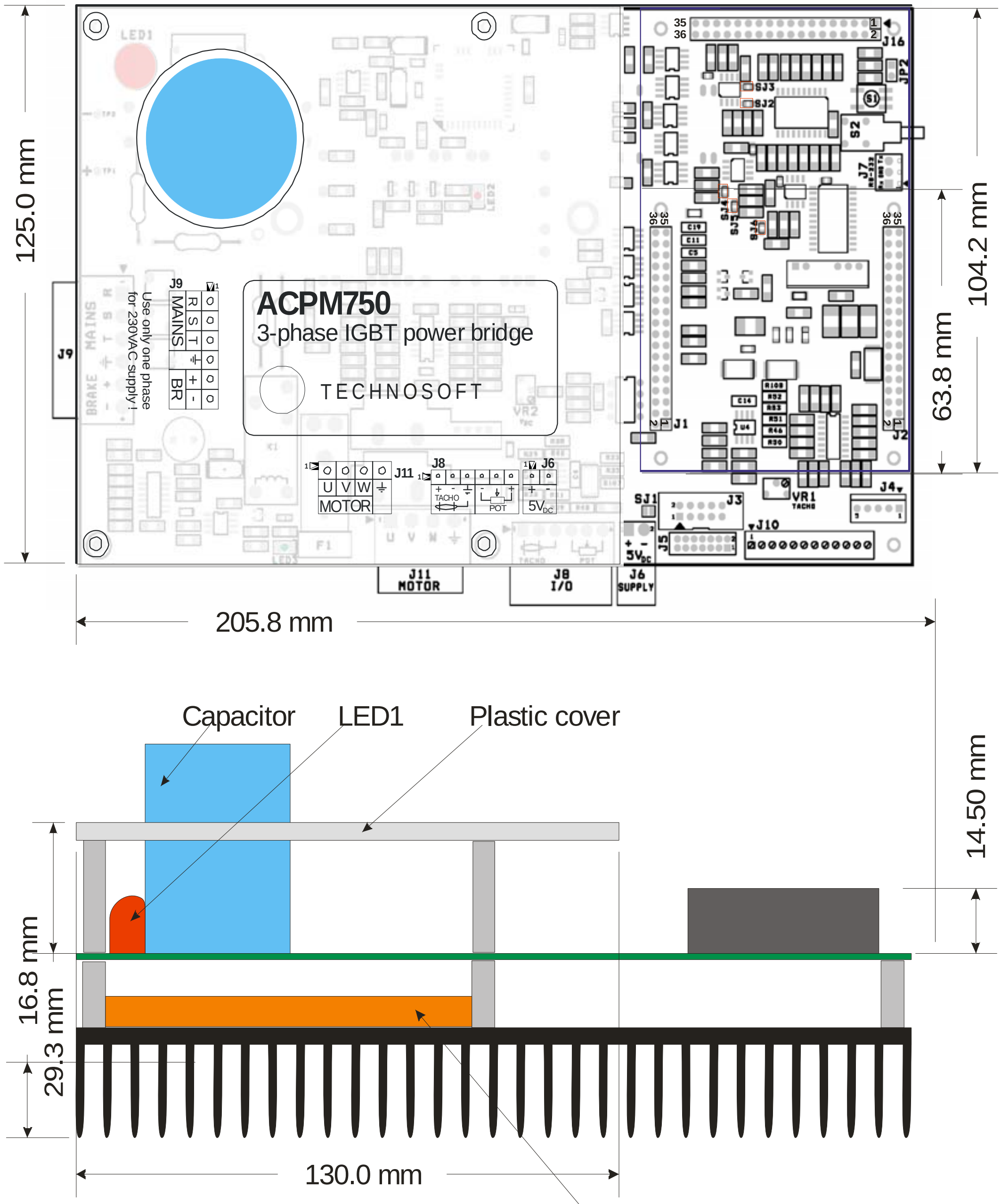
These links connect the Hall signals from ACPM750 v3.4 MC-Bus with three I/O pins of the MSK243.

Appendix D. MC-Bus Pin Correspondence with MSK28335 / MSK2812 / MSK2407

J16 – MC-bus connector

Pin	ACPM750 v3.4 signal (J16 connector)	MSK28335 signal (J3 connector)	MSK2812 signal (J3 connector)	MSK2407 signal (J3 connector)
1	n.c.	+3.3V	+3.3V	+3.3V
2	n.c.	+3.3V	+3.3V	+3.3V
3	PWM1(I)	PWM1A/ GPIO00 (o)	PWM1/ GPIOA0 (o)	PWM1/ IOPA6(o)
4	PWM2(I)	PWM1B/ CAP6/ FSRB/ GPIO01 (o)	PWM2/ GPIOA1 (o)	PWM2/ IOPA7(o)
5	PWM3(I)	PWM2A/ GPIO02 (o)	PWM3/ GPIOA2 (o)	PWM3/ IOPB0(o)
6	PWM4(I)	PWM2B/ CAP5/ CKRB/ GPIO03 (o)	PWM4/ GPIOA3 (o)	PWM4/ IOPB1(o)
7	PWM5(I)	PWM3A/ GPIO04 (o)	PWM5/ GPIOA4 (o)	PWM5/ IOPB2(o)
8	PWM6(I)	PWM3B/ CAP1/ FSRA/ GPIO05 (o)	PWM6/ GPIOA5 (o)	PWM6/ IOPB3(o)
9	ACPM Brake(I)	CAP5/ XD31/ GPIO48 (o)	T1PWM/ T1CMP/ GPIOA6 (o)	T1PWM/ IOPB4(o)
10	Hall 1 (o)	CAP6/ XD30/ GPIO49 (I)	T2PWM/ T2CMP/ GPIOA7 (I)	T2PWM/ IOPB5(I)
11	Hall 2 (o)	SDA/ SYNCI/ SOCA/ GPIO32 (I)	TDIRA / GPIOA11 (I)	TDIRA/ IOPB6(I)
12	Hall 3 (o)	SCL/SYNCO/SOCB/ GPIO33 (I)	TCLKINA / GPIOA12 (I)	TCLKINA/ IOPB7(I)
13	Encoder A (o)	QEP1A/ XD29/ GPIO50 (I)	CAP1 / QEP1 / GPIOA8 (I)	QEP1/ IOPA3(I)
14	Encoder B (o)	QEP1B/ XD28/ GPIO51 (I)	CAP2 / QEP2 / GPIOA9 (I)	QEP2/ IOPA4(I)
15	Encoder Z (o)	QEP1I/ XD26/ GPIO53 (I)	CAP3 / GPIOA10 (I)	CAP3/ IOPA5(I)
16	PDPINT (o)	TZ1/ CANTXB/ DXB/ GPIO12 (I)	#PDPINTA (I)	PDPINTA (I)
17	n.c.	QEP1S/ XD27/ GPIO52	XINT2/ ADCSOC/ GPIOE1	XINT2/ IOPD0
18	ACPM Err. Rst (I)	TZ2/ CANRXB/ DRB/ GPIO13 (o)	#T2CTRIP / GPIOD1 (o)	BIO/ IOPC1(o)
19	n.c.	SPISIMO/ GPIO54 (o)	SPISIMOA / GPIOF0 (o)	SPISIMO/ IOPC2(o)
20	n.c.	SPISOMI/ GPIO55 (I)	SPISOMIA_J3 (I)	SPISOMI/ IOPC3(I)
21	n.c.	SPICLK/ GPIO56 (o)	SPICLKA / GPIOF2 (o)	SPICLK/ IOPC4(o)
22	n.c.	SPISTE/ GPIO57 (o)	SPISTEA_J3 (o)	SPISTE/ IOPC5(o)
23	GND	GND	GND	GND
24	GND	GND	GND	GND
25	n.c.	+5V	+5V	+5V
26	n.c.	+5V	+5V	+5V
27	n.c.	VREFHI	VREFHI	VREFHI
28	VREFLO	VREFLO	VREFLO	VREFLO
29	n.c.	ADCINA0	ADCINA0	ADCIN00
30	n.c.	ADCINA1	ADCINA1	ADCIN01
31	ACPM Tacho (o)	ADCINA2 (I)	ADCINA2 (I)	ADCIN02 (I)
32	ACPM Ref (o)	ADCINA3 (I)	ADCINA3 (I)	ADCIN03 (I)
33	ACPM VDC (o)	ADCINA4 (I)	ADCINA4 (I)	ADCIN04 (I)
34	ACPM I_V (o)	ADCINA5 (I)	ADCINA5 (I)	ADCIN05 (I)
35	ACPM I_U (o)	ADCINA6 (I)	ADCINA6 (I)	ADCIN06 (I)
36	n.c.	VREFLO	ADCINA7 (I)	ADCIN07 (I)

Appendix E. ACPM750 Mechanical Drawings



This drawing is not to scale

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