# Stepnet *Plus* Module EtherCAT SEM

## Control Modes
- Indexer, Point-to-Point, PVT
- Camming, Gearing
- Position, Velocity, Torque (Servo Mode)
- Position (Microstepping)

## Command Interface
- CAN application layer over EtherCAT (CoE)
- ASCII and discrete I/O
- Stepper commands
- ±10V Velocity/torque command (servo mode)
- PWM Velocity/torque command (servo mode)
- Master encoder (Gearing/Camming)

## Communications
- EtherCAT
- RS-232

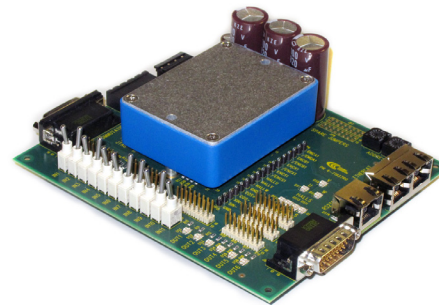## Feedback
*Incremental*
- Digital quad A/B encoder

## I/O
- Digital: 14 inputs, 6 outputs
- Analog: 1 input

## Dimensions: mm [in]
- 76.3 x 58.2 x 20.5 [3.01 x 2.29 x 0.81]

EtherCAT
Conformance tested



| Model | Ic | Ip | Vdc |
|---|---|---|---|
| SEM-090-07 | 5 | 7 | 14-90 |
| SEM-090-10 | 10 | 10 | 14-90 |



DEVELOPMENT KIT

## DESCRIPTION

*Stepnet SEM* is a high-performance, DC powered drive for control of stepper motors via EtherCAT, an Ethernet-based fieldbus. The SEM operates as an EtherCAT slave using the CAN application layer over EtherCAT (CoE). Supported modes include: Profile Position-Velocity, Cyclic Synchronous Position-Velocity (CSP, CSV), Interpolated Position Mode (PVT), and Homing.

With encoder feedback a stepper can be operated as a brushless servo motor enabling ±10V analog or digital PWM velocity or torque control in addition to EtherCAT. Direct position control from pulses in CW/CCW, Pulse/Dir, or Quad A/B encoder format works in either microstepping or servo modes.

Twelve high-speed digital inputs with programmable functions are provided, and a lower-speed input for a motor temperature switch.

An SLI (Switch & LED Interface) function is supported by another high-speed input and four high-speed digital outputs. If not used for SLI, the input and outputs are programmable for other functions. Two open-drain MOSFET outputs can drive loads powered up to 24 Vdc.

An RS-232 serial port provides a connection to Copley's CME2 software for commissioning, firmware upgrading, and saving configurations to flash memory.

Drive power is transformer-isolated DC from regulated or unregulated power supplies. An AuxHV input is provided for "keep-alive" operation permitting the drive power stage to be completely powered down without losing position information, or communications with the control system.

# Stepnet Plus Module EtherCAT — SEM

RoHS CE

## GENERAL SPECIFICATIONS

Test conditions: Load = Bipolar stepper: 2 mH + 2 Ω per phase.  Ambient temperature = 25°C, +HV = $HV_{max}$

| MODEL | SEM-090-07 | SEM-090-10 | |
|---|---|---|---|
| **OUTPUT POWER** | | | |
| Peak Current | 7 (5) | 10 (7.1) | Adc (Arms-sine), ±5% |
| Peak time | 1 | 1 | Sec |
| Continuous current | 5 (3.5) | 10 (7.1) | Adc (Arms-sine) per phase |
| Maximum Output Voltage | | | Vout = HV*0.97 - Rout*Iout |
| **INPUT POWER** | | | |
| HVmin~HVmax | +14 to +90 | +14 to +90 | Vdc Transformer-isolated |
| Ipeak | 7.7 | 11 | Adc (1 sec) peak |
| Icont | 5.5 | 11 | Adc continuous |
| Aux HV | +14 to +HV Vdc @ 500 mAdc maximum, 2.5 W | | |
| **PWM OUTPUTS** | | | |
| Type | Dual H-bridge MOSFET , 16 kHz center-weighted PWM, space-vector modulation | | |
| PWM ripple frequency | 32 kHz | | |

### CONTROL MODES

CAN application layer over EtherCAT (CoE):
Microstepping:Profile Position-Velocity, Cyclic Synchronous Position-Velocity, Interpolated Position (PVT), Homing
Servo mode: all of the microstepping modes, plus Cyclic Synchronout Torque (CST) mode
Analog ±10 Vdc current/velocity (servo mode), camming, internal indexer and function generator
Digital PWM/Polarity current/velocity (servo mode), CW/CCW, Step/Direction, and quad A/B encoder position commands

### COMMAND INPUTS

| | |
|---|---|
| Type | EtherCAT, galvanically isolated from drive circuits |
| Signals & format | TX+, TX–, RX+, RX–; 100BaseTX |
| Data protocol | CANopen Device Profile DSP-402 over EtherCAT (CoE) |
| Device ID Selection | Programmable, or via digital inputs |
| Analog | ±10 Vdc |
| Digital | High speed inputs for CW/CCW, Step/Direction, and quad A/B encoder |
| Camming | Quad A/B digital encoder |

### DIGITAL CONTROL

| | |
|---|---|
| Digital Control Loops | Current, velocity, position. 100% digital loop control |
| Sampling rate (time) | Current loop: 16 kHz (62.5 µs), Velocity & position loops: 4 kHz (250 µs) |
| Commutation | Sinusoidal, field-oriented control for brushless motors |
| Modulation | Center-weighted PWM with space-vector modulation |
| Bandwidths | Current loop: 2.5 kHz typical, bandwidth will vary with tuning & load inductance |
| HV Compensation | Changes in bus voltage do not affect bandwidth |
| Minimum load inductance | 200 µH line-line |

### DIGITAL INPUTS

| | |
|---|---|
| [IN1~9] | High-speed digital, 100 ns RC filter, 10 kΩ pull-up to +5 Vdc, +7 Vdc tolerant |
| | 74AHC14 Schmitt trigger, $V_T+$ = 3.5 Vdc max, $V_T-$ = 1.5 Vdc min, $V_H+$ = 0.45~1.50 Vdc |
| [IN10] | SLI port MISO input, 47 ns RC filter, 10 kΩ pull-up to +5 Vdc, +7 Vdc tolerant |
| | 74LVC2G14 Schmitt trigger, $V_T+$ = 2.05~3.35 Vdc, $V_T-$ = 1.1~2.15 Vdc, $V_H+$ = 0.65~1.6 Vdc |
| [IN11] | Motor temperature switch, 330 µs RC filter, 4.99 kΩ pull-up to +5 Vdc, +24V tolerant |
| | 74LVC2G14 Schmitt trigger, $V_T+$ = 2.05~3.35 Vdc, $V_T-$ = 1.1~2.15 Vdc, $V_H+$ = 0.65~1.6 Vdc |
| [IN12~14] | GP inputs, 1.5 µs RC filter, 15 kΩ pull-up to +5 Vdc, +24 Vdc tolerant |
| | 74AHC14 Schmitt trigger, $V_T+$ = 3.5 Vdc max, $V_T-$ = 1.5 Vdc min, $V_H+$ = 0.45~1.50 Vdc |

### DIGITAL OUTPUTS

| | |
|---|---|
| [OUT1~2] | Open-drain MOSFET with 1 kΩ pull-up with series diode to +5 Vdc |
| | 300 mAdc max, +30 Vdc max, external flyback diodes required if driving inductive loads |
| [OUT3~6 ] | SLI port MOSI, SCLK, EN1, & EN2 signals, 74AHCT125 line drivers; +5 Vdc tolerant |

### ANALOG INPUT

| | |
|---|---|
| Type | ±10 Vdc, 12-bit resolution, differential |

### FEEDBACK

*Incremental:*

| | |
|---|---|
| Digital Incremental Encoder | Quadrature signals, (A, /A, B, /B, X, /X), differential (X, /X Index signals not required) |
| 5 MHz maximum line frequency (20 M counts/sec) | |
| Encoder power | +5 Vdc ±2% @ 400 mAdc max, protected against shorts and overtemperature |

## RS-232 PORT

| | |
|---|---|
| Signals | RxD, TxD, Gnd for operation as a DTE device |
| Mode | Full-duplex, DTE serial port for drive setup and control, 9,600 to 115,200 Baud |
| Protocol | ASCII or Binary format |

## MOTOR CONNECTIONS

| | |
|---|---|
| Phases A, /A, B, /B | PWM outputs to 2-phase, 4-wire bipolar stepper motors |
| Digital Incremental Encoder | Quadrature signals, (A, /A, B, /B, X, /X), differential (X, /X Index signals not required) |
| | 5 MHz maximum line frequency (20 M counts/sec) |
| Encoder power | +5 Vdc ±2% @ 400 mAdc max |
| Motemp [IN11] | Motor overtemperature switch input. Active level programmable |
| | Programmable to disable drive when motor over-temperature condition occurs |

## PROTECTIONS

| | |
|---|---|
| HV Overvoltage | $+HV > HV_{max}$      Drive outputs turn off until   $+HV < HV_{max}$ (See Input Power for $HV_{max}$) |
| HV Undervoltage | $+HV < +14$ Vdc      Drive outputs turn off until   $+HV > +14$ Vdc |
| Drive over temperature | Heat plate > 70°C.      Drive outputs turn off |
| Short circuits | Output to output, output to ground, internal PWM bridge faults |
| $I^2T$ Current limiting | Programmable: continuous current, peak current, peak time |
| Motor over temperature | Digital inputs programmable to detect motor temperature switch |

## MECHANICAL & ENVIRONMENTAL

| | |
|---|---|
| Size mm [in] | 76.3 x 58.2 x 20.5 [3.01 x 2.29 x 0.81] |
| Weight | 0.27 lb (0.12 kg) without heatsink |
| Ambient temperature | 0 to +45°C operating, -40 to +85°C storage |
| Humidity | 0 to 95%, non-condensing |
| Vibration | 2 *g* peak, 10~500 Hz (sine), IEC60068-2-6 |
| Shock | 10 *g*, 10 ms, half-sine pulse, IEC60068-2-27 |
| Contaminants | Pollution degree 2 |
| Environment | IEC68-2: 1990 |
| Cooling | Heat sink and/or forced air cooling required for continuous power output |

## AGENCY STANDARDS CONFORMANCE

*In accordance with EC Directive 2014/30/EU (EMC Directive)*

| | |
|---|---|
| EN 55011: 2009/A1:2010 | CISPR 11:2009/A1:2010 |
| | Industrial, Scientific, and Medical (ISM) Radio Frequency Equipment – |
| | Electromagnetic Disturbance Characteristics – Limits and Methods of Measurement |
| | Group 1, Class A |
| EN 61000-6-1: 2007 | Electromagnetic Compatibility (EMC) – Part 6-1: Generic Standards – |
| | Immunity for residential, Commercial and Light-industrial Environments |

*In accordance with EC Directive 2014/35/EU (Low Voltage Directive)*

| | |
|---|---|
| IEC 61010-1:2010 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use |

*Underwriters Laboratory Standards*

| | |
|---|---|
| UL 61010-1, 3rd Ed.: 2012 | Electrical Equipment for Measurement, Control and Laboratory Use; |
| | Part 1: General Requirements |

*UL File Number E249894*

## COMMAND INPUTS

### ETHERCAT COMMUNICATIONS

EtherCAT is the open, real-time Ethernet network developed by Beckhoff based on the widely used 100BASE-TX cabling system. EtherCAT enables high-speed control of multiple axes while maintaining tight synchronization of clocks in the nodes. Data protocol is CANopen over EtherCAT (CoE) based on DSP-402 for motion control devices. More information on EtherCAT can be found on this web-site: http://ethercat.org/default.htm
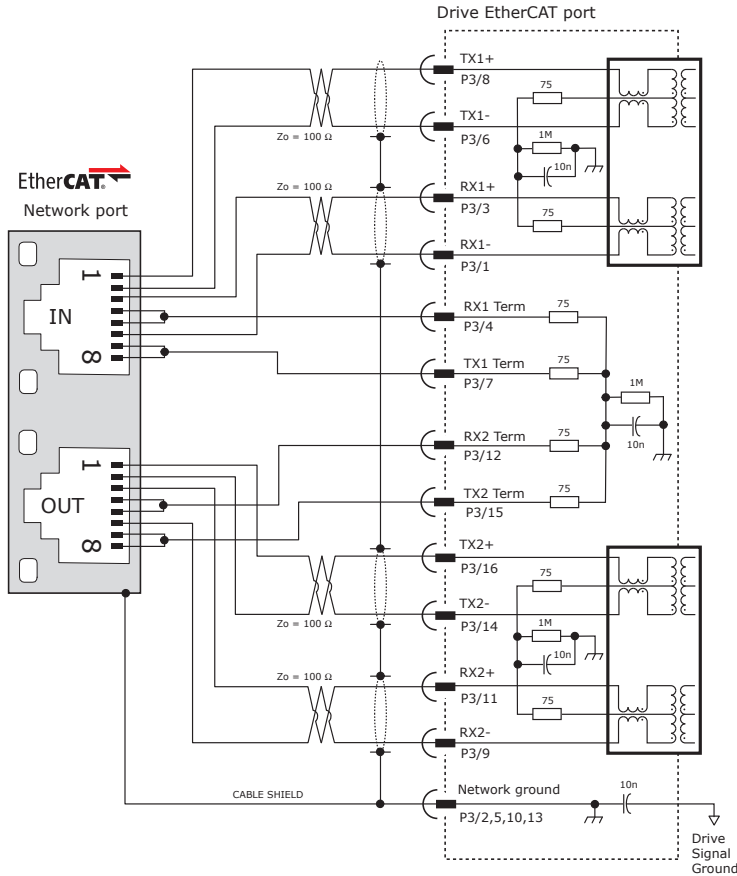


### ETHERCAT CONNECTIONS

Page 11 shows guidelines for PC board layout and designing for EtherCAT signals.

Page 13 shows the dual EtherCAT cable connections on the Development Kit.

CME2 -> Basic Setup -> Operating Mode Options

Command Source: CAN over EtherCat
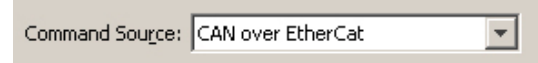
### RS-232 COMMUNICATIONS

*SEM* is configured via a three-wire, full-duplex DTE RS-232 port that operates from 9600 to 115,200 Baud, 8 bits, no parity, and one stop bit. Signal format is full-duplex, 3-wire, DTE using RxD, TxD, and Gnd. Connections to the *SEM* RS-232 port are through P2 The graphic below shows the connections between an *SEM* and a computer COM port which is a DTE device.

### RS232 PORT
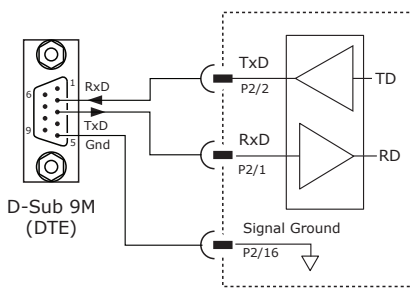
CME2 -> Tools -> Communications Wizard

## COMMAND INPUTS

### DIGITAL POSITION

Digital position commands can be in three formats: Pulse & Direction, Count-Up/Count-Down (CU/CD), and quad A/B encoder. The active edge of the waveforms is programmable and the ratio of input pulses to motor microsteps is programmable, too. The Invert Command selection will reverse the direction of motion commanded by the inputs without changing the wiring.
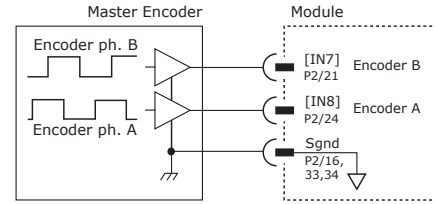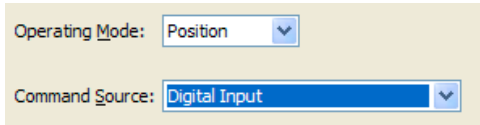
#### PULSE & DIRECTION
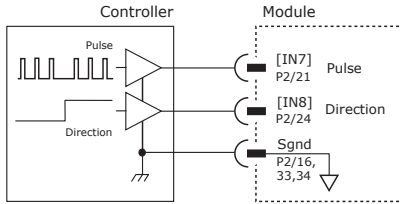
#### CU/CD
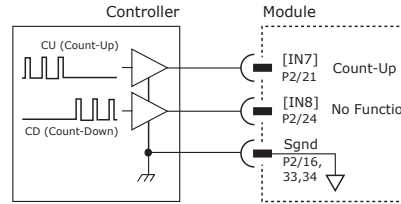
#### QUAD A/B ENCODER



CME2 -> Basic Setup -> Operating Mode Options

CME2 -> Basic Setup -> Operating Mode Options



### DIGITAL VELOCITY

Digital velocity commands are PWM signals in two formats: PWM 50% is a single signal that commands 0 at 50% duty cycle, with increasing or decreasing duty cycle to command positive or negative values. PWM & Direction format uses a PWM signal that goes from 0% to 100% to command magnitude while a 0/1 at the Dir input commands direction.
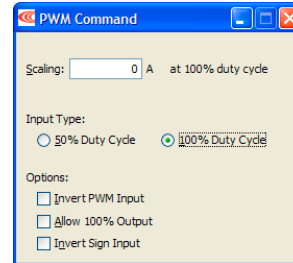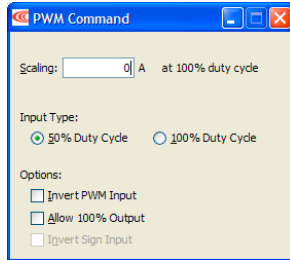
#### PWM 50%
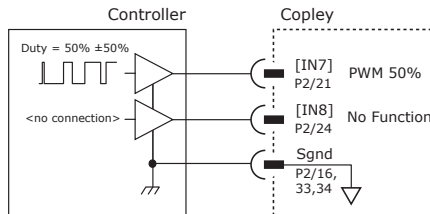
#### PWM & DIRECTION
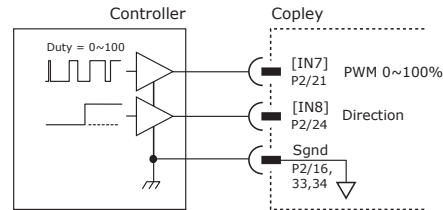


CME2 -> PWM Command block

CME2 -> PWM Command block

### DIGITAL COMMAND FAIL-SAFE

In the position and velocity modes above, the 0% and 100% conditions can be programmed to command zero output. This is to protect against conditions that can occur with broken or disconnected cables which might produce uncontrolled motion.

## SERVO MODE

Servo mode operates a stepper like a brushless servo motor taking position feedback from an encoder and controlling position, velocity, or torque. Command inputs include all of the digital inputs and modes as well as the ±10V analog input which can control position, velocity, and current.

## ANALOG COMMAND INPUT

In addition to the digital position and velocity inputs on the preceding page, the analog input can be used to control position, velocity, and torque.

CME2 -> Basic Setup -> Feedback Options

Motor Encoder: Primary Incremental
⦿ Differential  ◯ Single Ended
☑ Run in Servo Mode

CME2 -> Basic Setup -> Operating Mode Options

Operating Mode: Position
Command Source: Analog Command

CME2 -> Basic Setup -> Operating Mode Options
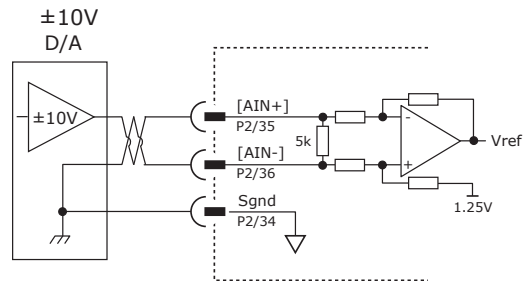
Command Source: Analog Command

CME2 -> Main Page -> Analog Command block

Scaling: 4000 counts = 10V
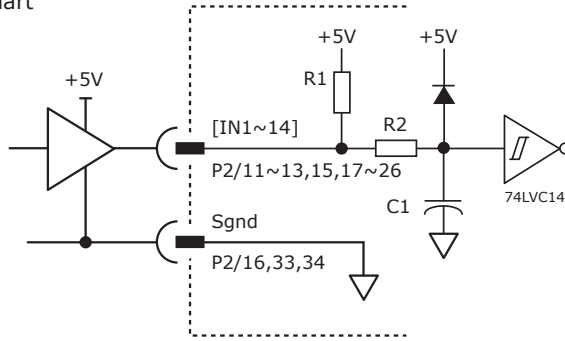Dead Band: 0 mV
☐ Invert Command
Analog Input Filter

±10V
D/A

±10V

[AIN+]
P2/35
[AIN-]
P2/36
Sgnd
P2/34

5k

Vref

1.25V

## INPUT-OUTPUT

### HIGH SPEED DIGITAL INPUTS
Vin tolerance see chart

| Input | P2 Pin | R1 | R2 | C1 | Vin |
|-------|--------|------|------|------|------|
| IN1 | 15 | | | | |
| IN2 | 18 | | | | |
| IN3 | 17 | | | | |
| IN4 | 20 | | | | |
| IN5 | 19 | 10k | 1k | 100p | 7V |
| IN6 | 22 | | | | |
| IN7 | 21 | | | | |
| IN8 | 24 | | | | |
| IN9 | 23 | | | | |
| IN10 | 26 | | | 47p | |
| IN11 | 25 | 4.99k | 10k | 33n | |
| IN12 | 11 | | | | 24 |
| IN13 | 13 | 15k | 15k | 100p | |
| IN14 | 12 | | | | |

### DIGITAL OUTPUTS

Vout max (see chart)          5V max
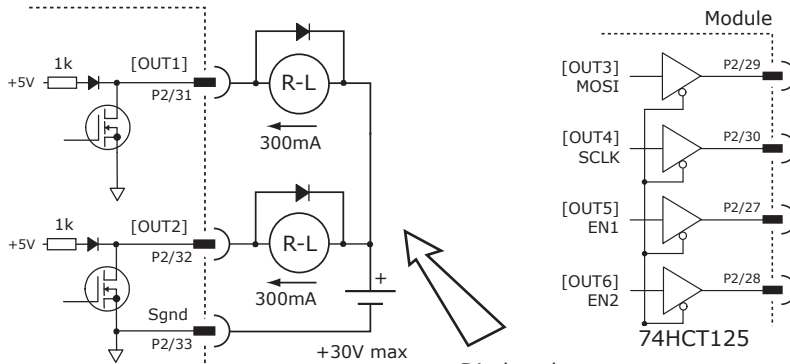
| Output | P2 Pin | Vout |
|--------|--------|------|
| OUT1 | 31 | 30 |
| OUT2 | 32 | |
| OUT3 | 29 | |
| OUT4 | 30 | 5 |
| OUT5 | 27 | |
| OUT6 | 28 | |

Diodes shown on outputs must be supplied
when driving inductive loads.

## ETHERCAT DEVICE ID (STATION ALIAS) SWITCHES

The SLI (Switch & LED Interface) port takes in the 8 signals from the two BCD encoded switches that set the Ether-
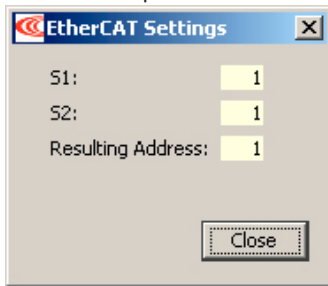CAT Device ID and controls the LEDs on the EtherCAT port connectors.
The graphic below shows the circuit for reading the EtherCAT Device ID switches.
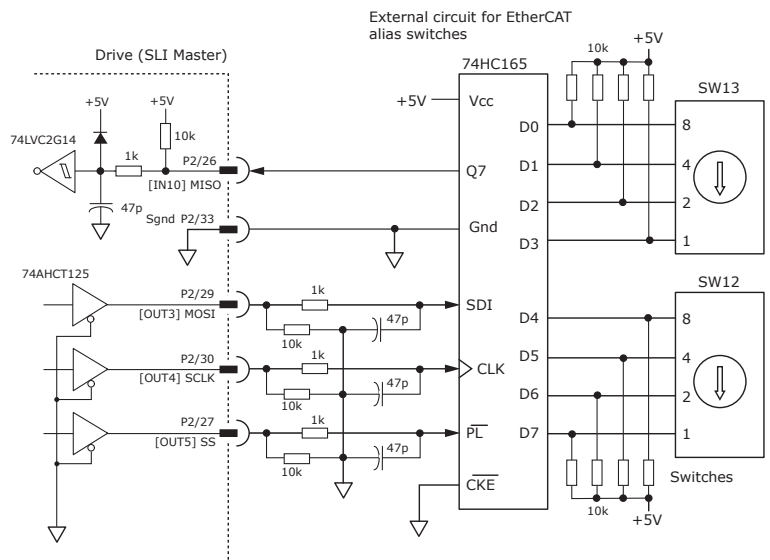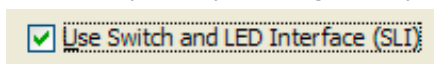The 74HC165 works as a parallel-in/serial-out device.
The 10k pull-down resistors pull the shift register inputs to ground when the SEM is initializing.
In the graphics below, switch SW13 is "S2" and SW12 is "S1". The values of S1 are 16~255 and of S2 are 0~15.
Together they provide Device ID range of 0~255.

CME2 -> Amplifier -> Network Configuration

**EtherCAT Settings**
S1:  1
S2:  1
Resulting Address:  1
Close

CME2 -> Input/Output -> Digital Outputs

☑ Use Switch and LED Interface (SLI)

## MOTOR CONNECTIONS

Motor connections consist of: phases, encoder, thermal sensor, and brake. The phase connections carry the drive output currents that drive the motor to produce motion. The Hall signals are three digital signals that give absolute position feedback within an electrical commutation cycle. The encoder signals give incremental position feedback and are used for velocity and position modes, as well as sinusoidal commutation. A thermal sensor that indicates motor overtemperature is used to shut down the drive to protect the motor. A brake can provide a fail-safe way to prevent movement of the motor when the drive is shut-down or disabled.

## QUAD A/B INCREMENTAL ENCODER

Encoders with differential line-driver outputs provide incremental position feedback via the A/B signals and the optional index signal (X) gives a once per revolution position mark.

### DIGITAL QUADRATURE ENCODER INPUT
5V
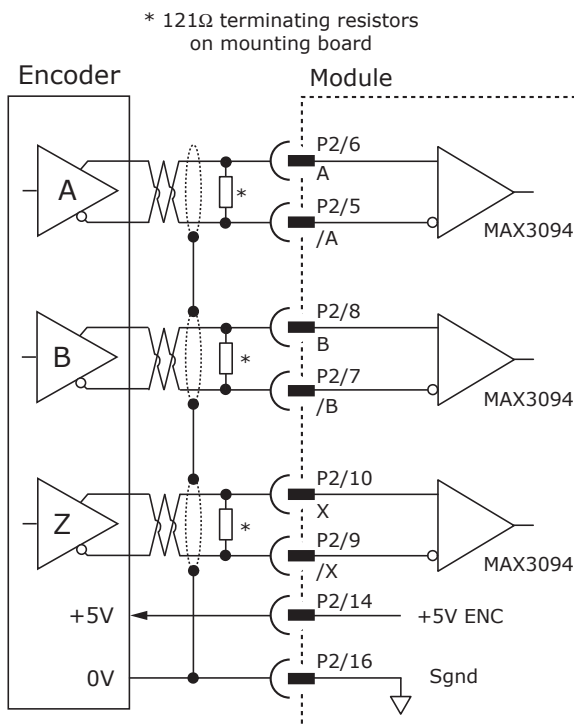


CME2 -> Motor/Feedback -> Feedback

Motor Encoder: Primary Incremental
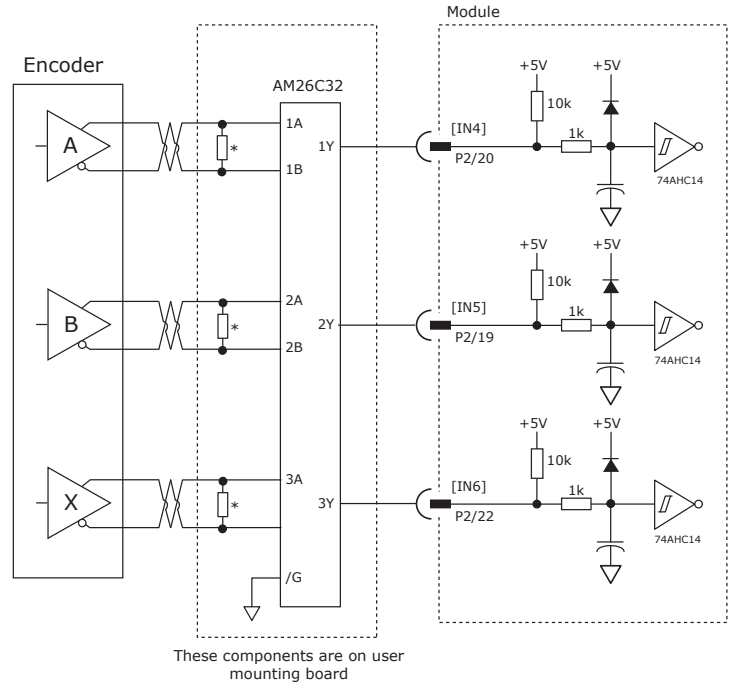
## MOTOR CONNECTIONS (CONT'D)

### SECONDARY QUAD A/B/X INCREMENTAL ENCODER

Digital inputs [IN4,5,6] can be programmed as secondary encoder inputs. The graphic shows a differential line receiver on the user mounting board to convert typical encoder signals into single-ended ones for the secondary inputs. Single-ended encoders would connect directly to the inputs of the AEM.

CME2 -> Basic Setup -> Feedback Options
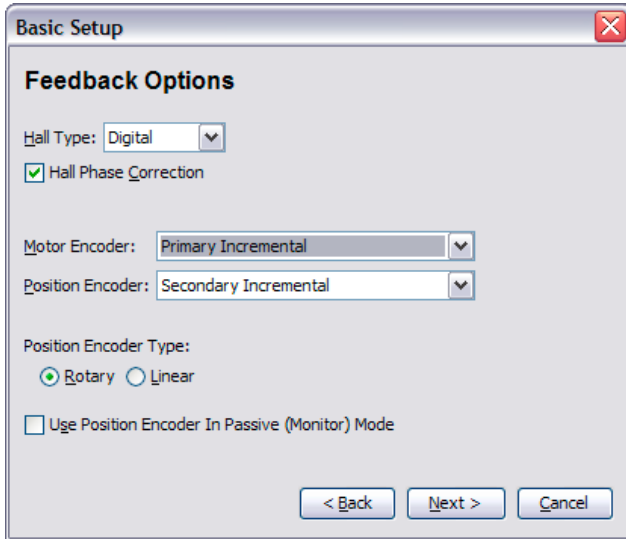
The CME2 screen above shows a Primary Incremental encoder for the motor input. Other types of encoders can be selected for this function. The secondary encoder input can be used for either motor or position feedback.

These components are on user mounting board

## MOTOR CONNECTIONS (CONT'D)

### PHASE CONNECTIONS

The drive output is a three-phase PWM inverter that converts the DC bus voltage (+HV) into three sinusoidal voltage waveforms that drive the motor phase-coils. Cable should be sized for the continuous current rating of the drive. Motor cabling should use twisted, shielded conductors for CE compliance, and to minimize PWM noise coupling into other circuits. The motor cable shield should connect to motor frame and the drive HV ground terminal (J2-1) for best results. When driving a DC motor, the W output is unused and the motor connects between the U & V outputs.
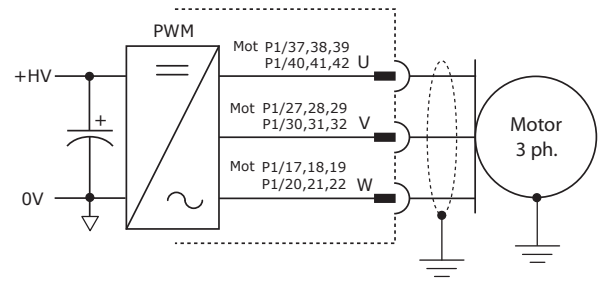
CME2 -> Basic Setup -> Motor Options

Motor Family:
⦿ Bru<u>s</u>hless ◯ Bru<u>s</u>h
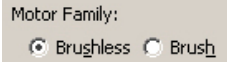
### MOTOR OVER TEMP INPUT

The 4.99k pull-up resistor works with PTC (positive temperature coefficient) thermistors that conform to BS 4999 : Part 111 : 1987 (table below), or switches that open/close indicating a motor over-temperature condition. The active level is programmable.

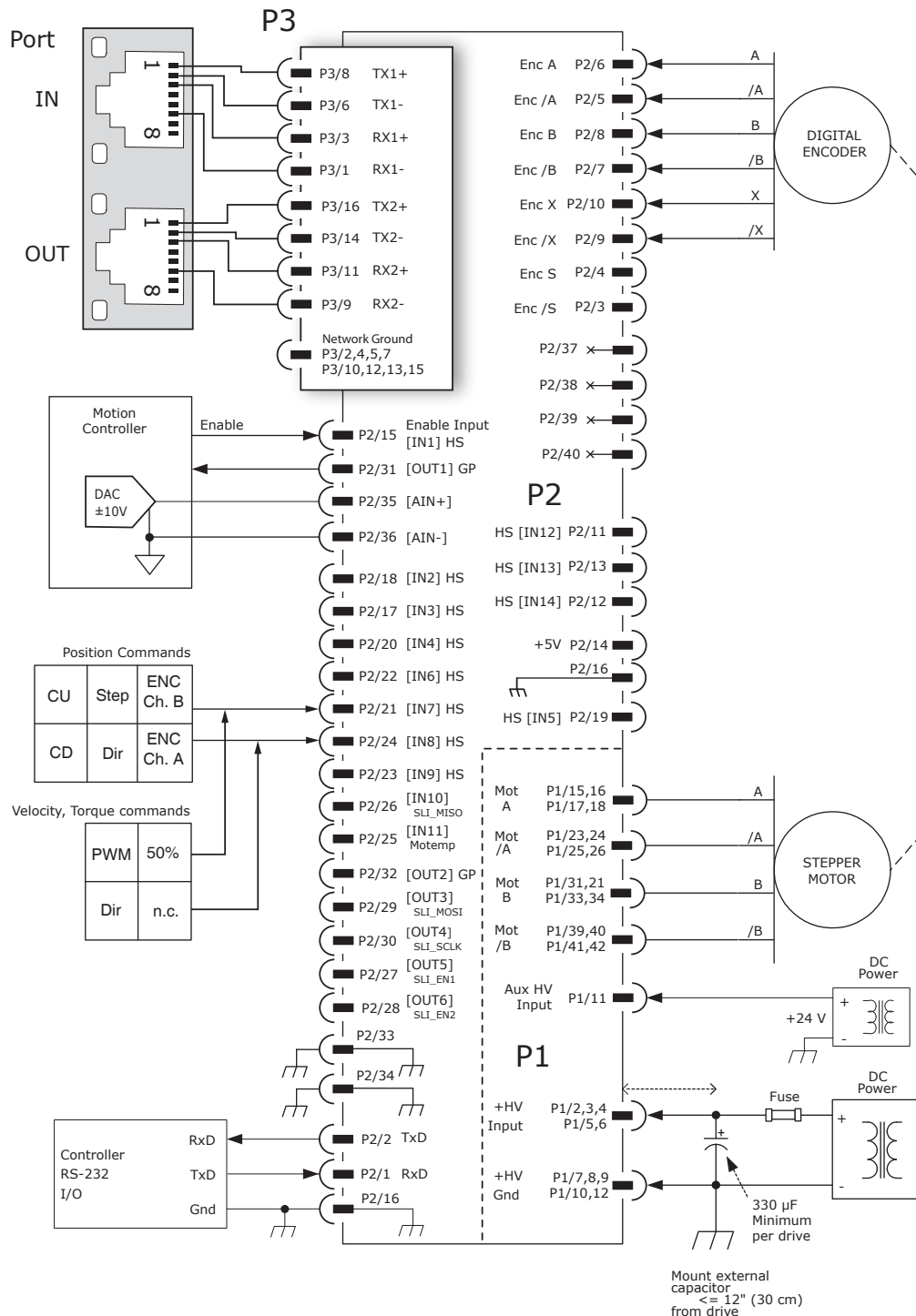| Property | Ohms |
|---|---|
| Resistance in the temperature range 20°C to +70°C | 60~750 |
| Resistance at 85°C | ≤1650 |
| Resistance at 95°C | ≥3990 |
| Resistance at 105°C | ≥12000 |

CME2 -> Input / Output

[IN5]  Motor Temp-HI Disables    ▼    0  ms
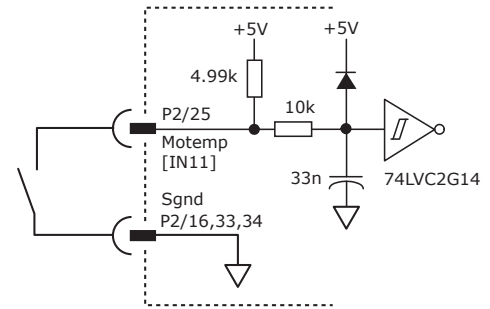
## CONNECTIONS FOR INCREMENTAL DIGITAL ENCODER



Notes:
1. P3 connections use multiple pins to share current.
   *All signals of the same name must be connected* on the PC board to which the SEM is mounted.
2. The EtherCAT connector is shown to illustrate connections between the SEM and external cabling.
   The connector is not part of the SEM and non-signal connections are not shown.

## PRINTED CIRCUIT BOARD CONNECTORS & SIGNALS

### P1 POWER & MOTOR

| Signal | Pin | | Signal |
|---|---|---|---|
| +HV | 2 | 1 | |
| +HV | 4 | 3 | +HV |
| +HV | 6 | 5 | +HV |
| HVGnd | 8 | 7 | HVGnd |
| HVGnd | 10 | 9 | HVGnd |
| HVGnd | 12 | 11 | HVAux |
| | 14 | 13 | |
| Mot A+ | 16 | 15 | Mot A+ |
| Mot A+ | 18 | 17 | Mot A+ |
| | 20 | 19 | |
| | 22 | 21 | |
| Mot A- | 24 | 23 | Mot A- |
| Mot A- | 26 | 25 | Mot A- |
| | 28 | 27 | |
| | 30 | 29 | |
| Mot B+ | 32 | 31 | Mot B+ |
| Mot B+ | 34 | 33 | Mot B+ |
| | 36 | 35 | |
| | 38 | 37 | |
| Mot B- | 40 | 39 | Mot B- |
| Mot B- | 42 | 41 | Mot B- |

P1: Power & Motor
Dual row, 2 mm- centers
48 position female header
SAMTEC SQW-121-01-L-D

### TOP VIEW

Viewed from above looking down on the connectors or PC board footprint to which the module is mounted



Pin 1
Pin 2
P3
Pin 16
Pin 1
P1
P2
Pin 48
Pin 40

### P3 ETHERCAT

| Signal | Pin | | Signal |
|---|---|---|---|
| NetGnd | 2 | 1 | RX1- |
| RX1 Term | 4 | 3 | RX1+ |
| TX1- | 6 | 5 | NetGnd |
| TX1+ | 8 | 7 | TX1 Term |
| NetGnd | 10 | 9 | RX2- |
| RX2 Term | 12 | 11 | RX2+ |
| TX 2- | 14 | 13 | NetGnd |
| TX2+ | 16 | 15 | TX2 Term |

P3: EtherCAT
Dual row, 2 mm- centers
16 position female header
SAMTEC SQW-108-01-L-D

### P2 CONTROL

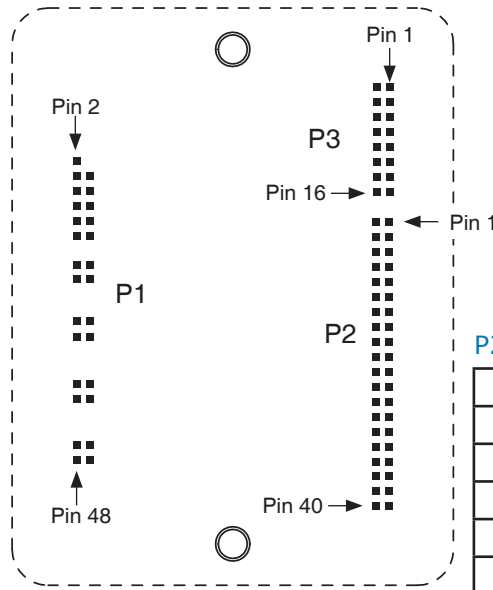| Signal | Pin | | Signal |
|---|---|---|---|
| RS-232 TxD | 2 | 1 | RS-232 RxD |
| Enc S | 4 | 3 | Enc /S |
| Enc A | 6 | 5 | Enc /A |
| Enc B | 8 | 7 | Enc /B |
| Enc X | 10 | 9 | Enc /X |
| HS [IN14] | 12 | 11 | [IN12] HS |
| Enc +5V Out | 14 | 13 | [IN13] HS |
| Sgnd | 16 | 15 | [IN1] Enable HS |
| HS [IN2] | 18 | 17 | [IN3] HS |
| HS [IN4] | 20 | 19 | [IN5] HS |
| HS [IN6] | 22 | 21 | [IN7] HS |
| HS [IN8] | 24 | 23 | [IN9] HS |
| MISO [IN10] | 26 | 25 | [IN11] Motemp |
| EN2 [OUT6] | 28 | 27 | [OUT5] EN1 |
| SCLK [OUT4] | 30 | 29 | [OUT3] MOSI |
| GP [OUT2] | 32 | 31 | [OUT1] GP |
| Sgnd | 34 | 33 | Sgnd |
| [AIN-] | 36 | 35 | [AIN+] |
| N.C. | 38 | 37 | N.C. |
| N.C. | 40 | 39 | N.C. |

P2: Control
Dual row, 2 mm- centers
40 position female header
SAMTEC SQW-120-01-L-D

Notes:
1. P1 connections use multiple pins to share current. *All signals of the same name must be connected* on the PC board to which the SEM is mounted.
2. Cells in table above that are filled in grey are connector contacts that have no circuit connections.
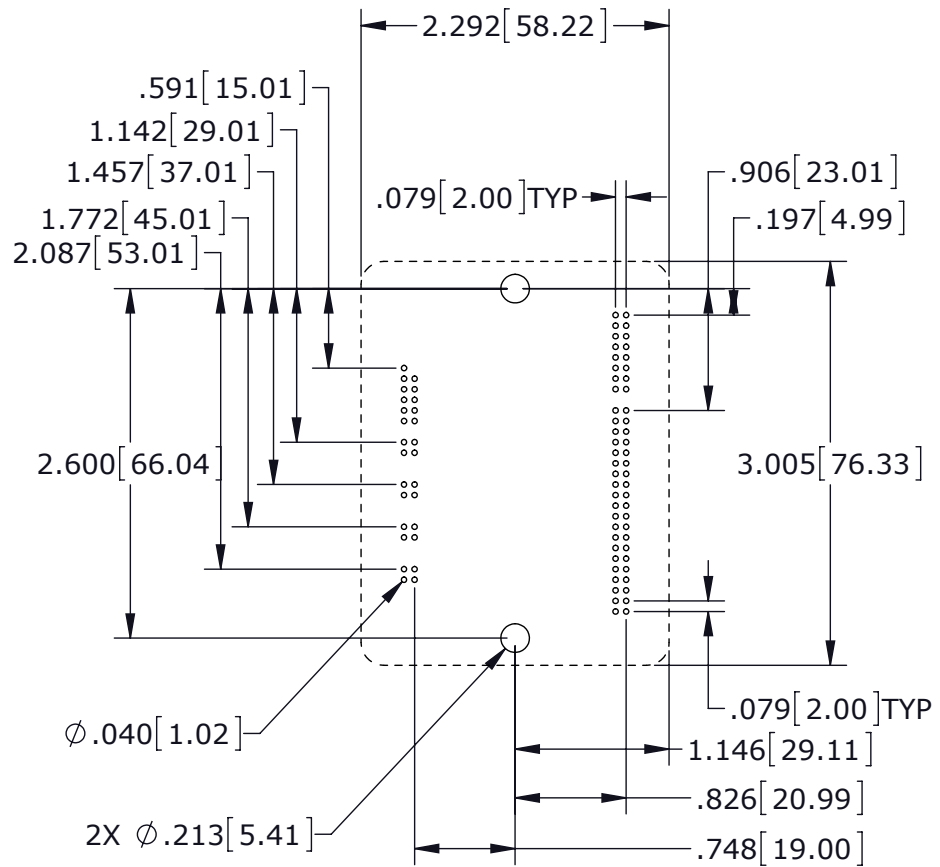   These pins are shown in grey outline in the Top View above.

## PRINTED CIRCUIT BOARD FOOTPRINT

Dimensions are in[mm]

TOP VIEW

Viewed from above looking down on
the connectors or PC board footprint to
which the module is mounted

P1 Signal Grouping
for current-sharing
See Note 1

2.292[58.22]

.591[15.01]
1.142[29.01]
1.457[37.01]
1.772[45.01]
2.087[53.01]

.079[2.00]TYP

.906[23.01]
.197[4.99]

2.600[66.04]

3.005[76.33]

Ø.040[1.02]

.079[2.00]TYP

1.146[29.11]
.826[20.99]

2X Ø.213[5.41]

.748[19.00]

PCB Hardware:

| Qty | Description | Mfgr | Part Number | Remarks |
|---|---|---|---|---|
| 1 | Socket Strip | Samtec | SQW-121-01-L-D | J1 HV & Motor |
| 1 | Socket Strip | Samtec | SQW-120-01-L-D | J2 Control |
| 1 | Socket Strip | Samtec | SQW-108-01-L-D | J3 CANopen |
| 2 | Standoff | PEM | KFE-4/40-8ET | #4/40 X 1/4" |

Additional Hardware (not shown above)

2    Screw, #4-40 x 1.25" Phillips Pan Head External Tooth Lockwasher SEMS, Stainless, or steel with nickel plating, Torque to 3~5 lb-in (0.34~0.57 N·m)
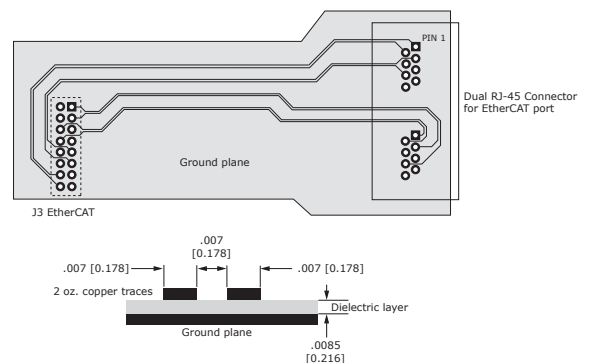
Notes

1. J1 signals of the same name must be connected for current-sharing (see graphic above).

2. To determine copper width and thickness for J3 signals refer to specification IPC-2221.
   (Association Connecting Electronic Industries, http://www.ipc.org)

3. Standoffs or mounting screws should connect to etch on pc board that connect to frame ground for maximum noise suppression and immunity.
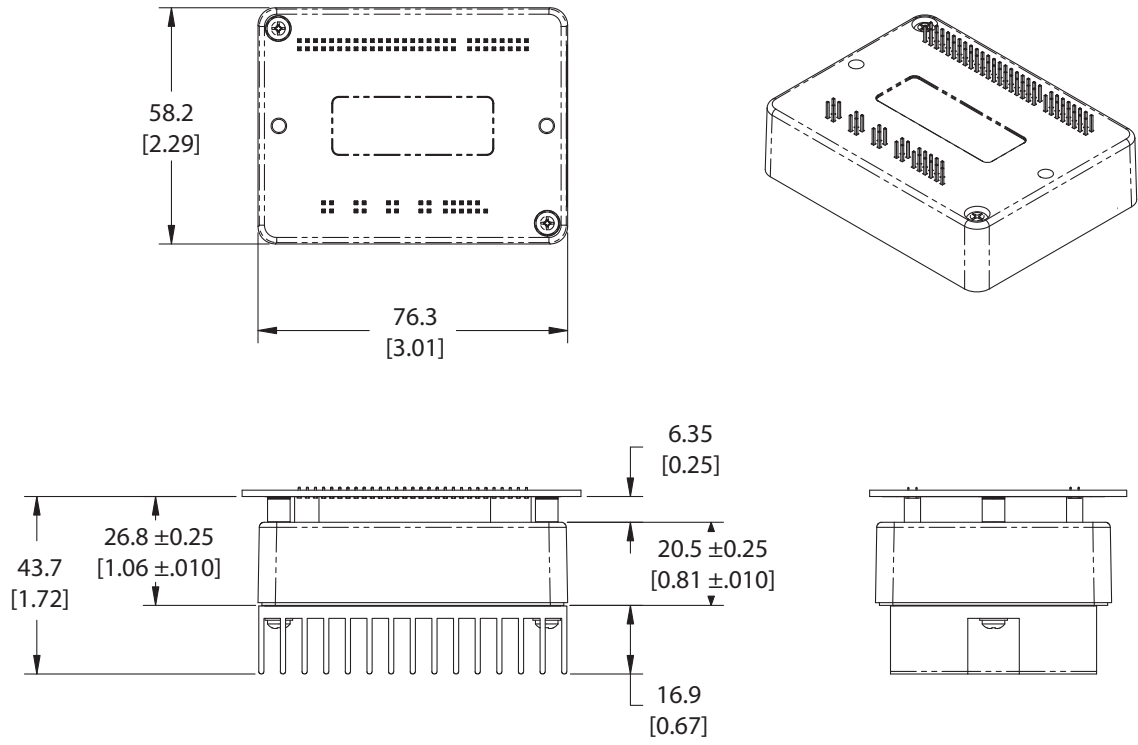
## PRINTED CIRCUIT BOARD DESIGN FOR ETHERCAT SIGNALS

EtherCAT signal routing must produce a controlled impedance to maintain signal quality. This graphic shows some principles of PC board design that should be followed. Traces for differential signals must have controlled spacing trace-trace, trace thickness, and spacing above a ground plane. All these things and the properties of the dielectric between ground plane and signals affect the impedance of the traces.
The dimensions shown here are typical.
The graphic on p. 4 detailing the EtherCAT connections shows resistors and a capacitor in the drive for terminating the unused conductors. As an alternative to adding traces back to the drive connector J3 for these signals, the same parts can be placed on the board at the RJ-45 connector, leaving only the differential EtherCAT signals to be routed with controlled impedance.

PIN 1

Dual RJ-45 Connector
for EtherCAT port

Ground plane

J3 EtherCAT

.007
[0.178]

.007 [0.178]

.007 [0.178]

2 oz. copper traces

Dielectric layer

Ground plane

.0085
[0.216]

DIMENSIONS

58.2
[2.29]

76.3
[3.01]

6.35
[0.25]

26.8 ±0.25
[1.06 ±.010]

43.7
[1.72]

20.5 ±0.25
[0.81 ±.010]

16.9
[0.67]

Dimensions: mm [in]

ACTIVITY (yellow)       LINK (green)

## DESCRIPTION

The Development Kit provides mounting and connectivity for one SEM drive. Solderless jumpers ease configuration of inputs and outputs to support their programmable functions. Switches can be jumpered to connect to digital inputs 1~11 so that these can be toggled to simulate equipment operation. Six LED's provide status indication for the digital outputs. Dual EtherCAT connectors make daisy-chain connections possible so that other EtherCAT devices such as Copley's Stepnet Plus or Xenus Plus Ethercat drives can easily be connected.
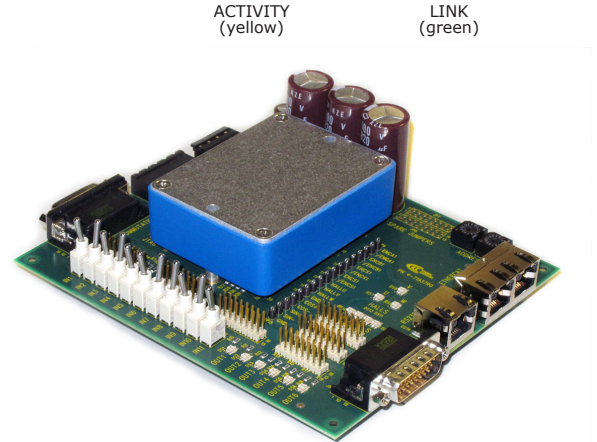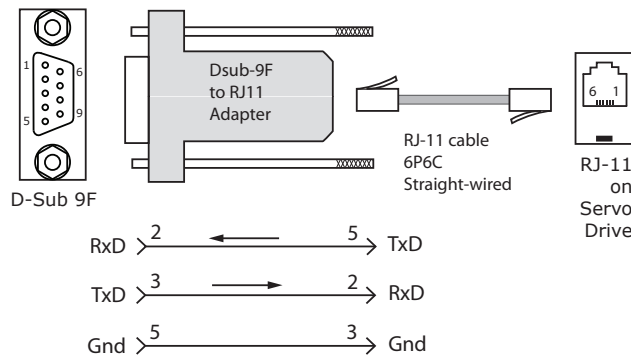
## RS-232 CONNECTION

The RS-232 port is used to configure the drive for stand-alone applications, or for configuration before it is installed into an EtherCAT network. CME 2™ software communicates with the drive over this link and is then used for complete drive setup. The EtherCAT Slave Device ID that is set by the rotary switch can be monitored, and a Device ID offset programmed as well.

The RS-232 connector, J9, is a modular RJ-11 type that uses a 6-position plug, four wires of which are used for RS-232. A connector kit is available (SER-CK) that includes the modular cable, and an adaptor to interface this cable with a 9-pin RS-232 port on a computer.

**P7**
RS-232

6 5 4 3 2 1

TxD          RxD
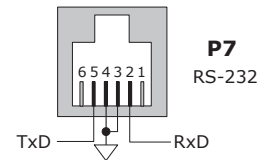
## SER-CK SERIAL CABLE KIT

The SER-CK provides connectivity between a D-Sub 9 male connector and the RJ-11 connector J9 on the Development Kit. It includes an adapter that plugs into the COM1 (or other) port of a PC and uses common modular cable to connect to the XEL. The connections are shown in the diagram below.

Dsub-9F to RJ11 Adapter

RJ-11 cable 6P6C Straight-wired

RJ-11 on Servo Drive

D-Sub 9F

| | | |
|---|---|---|
| RxD | 2 → 5 | TxD |
| TxD | 3 → 2 | RxD |
| Gnd | 5 → 3 | Gnd |

ℹ️ Don't forget to order a Serial Cable Kit SER-CK when placing your order for an SEM Development Kit!

## ETHERCAT CONNECTIONS

Dual RJ-45 sockets accept standard Ethernet cables. The IN port connects to a master, or to the OUT port of a device that is 'upstream', between the Stepnet and the master. The OUT port connects to 'downstream' nodes. If Stepnet is the last node on a network, only the IN port is used. No terminator is required on the OUT port.

## ETHERCAT STAT LED

The bi-color STAT LED combines the functions of the RUN and ERR LEDs.
Green and red colors alternate, and each color has a separate meaning:

Green is the "RUN" or EtherCAT State Machine:

| | | |
|---|---|---|
| Off | = | INIT state |
| Blinking | = | PRE-OPERATIONAL |
| Single Flash | = | SAFE-OPERATIONAL |
| On | = | OPERATIONAL |

Red is the "ERR" indicator:

| | | |
|---|---|---|
| Blinking | = | Invalid configuration |
| Single Flash | = | Unsolicited state change |
| Double Flash | = | Application watchdog timeout |
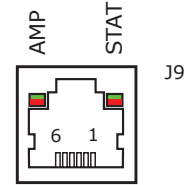
## L/A (LINK/ACT) LED

A green LED indicates the state of the EtherCAT network:

| LED | Link | Activity | Condition |
|---|---|---|---|
| ON | Yes | No | Port Open |
| Flickering | Yes | Yes | Port Open with activity |
| Off | No | (N/A) | Port Closed |
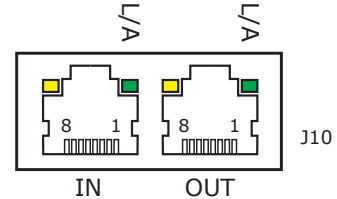
## AMP LED

A bi-color LED gives the state of the SEM drive. Colors do not alternate, and can be solid ON or blinking. When multiple conditions occur, only the top-most condition will be displayed. When that condition is cleared the next one below will shown.

1) Red/Blinking = Latching fault. Operation will not resume until drive is Reset.
2) Red/Solid = Transient fault condition. Drive will resume operation when the condition causing the fault is removed.
3) Green/Slow-Blinking = Drive OK but NOT-enabled. Will run when enabled.
4) Green/Fast-Blinking = Positive or Negative limit switch active. Drive will only move in direction not inhibited by limit switch.
5) Green/Solid = Drive OK and enabled. Will run in response to reference inputs or EtherCAT commands.

Latching Faults

Defaults
- Short circuit (Internal or external)
- Drive over-temperature
- Motor over-temperature
- Feedback Error
- Following Error

Optional (programmable)
- Over-voltage
- Under-voltage
- Motor Phasing Error
- Command Input Fault

## EtherCAT DEVICE ID

In an EtherCAT network, slaves are automatically assigned fixed addresses based on their position on the bus. When a device must have a positive identification that is independent of cabling, a Device ID is needed. In the SEM DevKit, this is provided by two 16-position rotary switches with hexadecimal encoding. These can set the Device ID of the drive from 0x01~0xFF (1~255 decimal). The chart shows the decimal values of the hex settings of each switch.
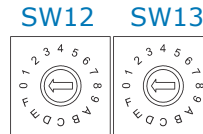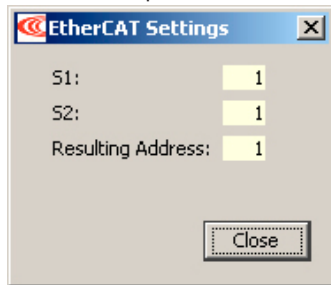
Example 1: Find the switch settings for decimal Device ID 107:

1) Find the highest number under S1 that is less than 107 and set S1 to the hex value in the same row:
96 < 107 and 112 > 107, so S1 = 96 = Hex 6
2) Subtract 96 from the desired Device ID to get the decimal value of switch S2 and set S2 to the Hex value in the same row:
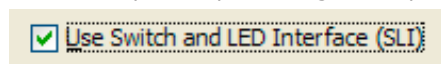S2 = (107 - 96) = 11 = Hex B

CME2 -> Amplifier -> Network Configuration

CME2 -> Input/Output -> Digital Outputs

EtherCAT
Device ID Switch
Decimal values

| | S1 | S2 |
|---|---|---|
| HEX | DEC | |
| 0 | 0 | 0 |
| 1 | 16 | 1 |
| 2 | 32 | 2 |
| 3 | 48 | 3 |
| 4 | 64 | 4 |
| 5 | 80 | 5 |
| 6 | 96 | 6 |
| 7 | 112 | 7 |
| 8 | 128 | 8 |
| 9 | 144 | 9 |
| A | 160 | 10 |
| B | 176 | 11 |
| C | 192 | 12 |
| D | 208 | 13 |
| E | 224 | 14 |
| F | 240 | 15 |

## ETHERCAT DEVICE ID (STATION ALIAS) SWITCH CONNECTIONS

The graphic below shows the connections to the EtherCAT Device ID switches. These are read after the drive is reset, or powered-on. When changing the settings of the switches, be sure to either reset the drive, or to power it off-on. Outputs [OUT3,4,5] and input [IN10] operate as an SLI (Switch & LED Interface) port which reads the settings on the EtherCAT Device ID switches, and controls the LEDs on the serial and EtherCAT port connectors.

The jumpers marked with red "X" should be removed so that SW10, or external connections to the signals do not interfere with the operation of the SLI port. The "X" on [OUT3] shows that no connections should be made to this by the user when the SLI port is active.
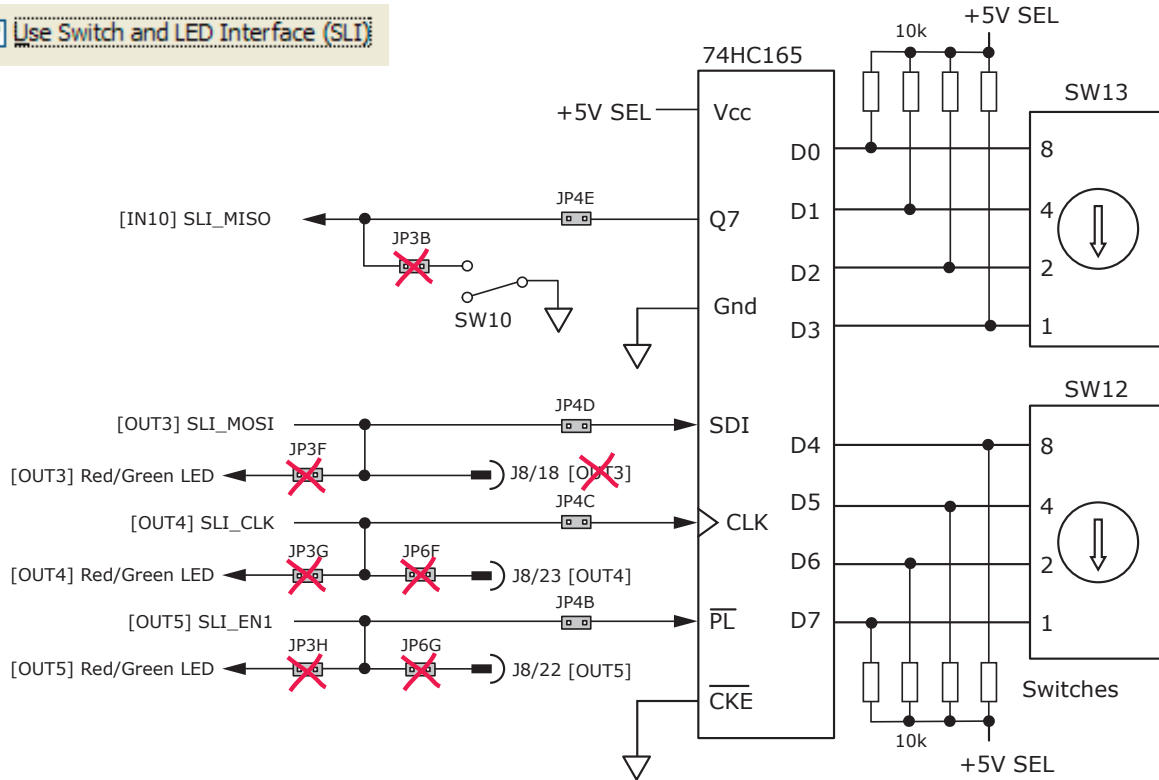


## 5V POWER SOURCES

The feedback connector J7 has connections for two power supplies:
  Pin 6 has +5V supplied by the SEM module
  Pin 17 connects to jumper J4 for the selection of the 5V power source:
  On J4, when the jumper connects pins 2 & 3, the power source is the SEM internal supply (the default setting)
  When the jumper is on pins 1 & 2, the power source comes from an external power supply connecting to J5-1.

5V power on the Development Kit that comes from the selectable 5V power source on J4 is labeled "5V SEL".

Circuits powered by 5V supplied only by the SEM are labeled "5V SEM"
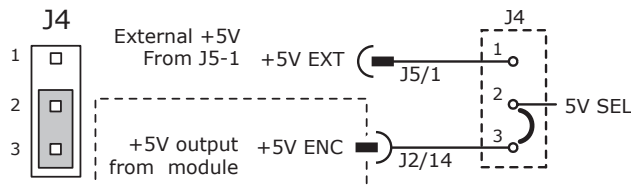
## LOGIC INPUTS & SWITCHES

The Development Kit has jumpers that can connect the SEM digital inputs to switches on the kit, or to the Signal connector J8.

As delivered, all of these jumpers are installed as shown. If connecting to external devices that actively control the level of an input, it is desirable to disconnect the switch which could short the input to ground.

For example, if [IN1] is connected to an external device for the Enable function, then jumper JP2A should be removed to take the switch SW1 out of the circuit. The figure below shows these connections.
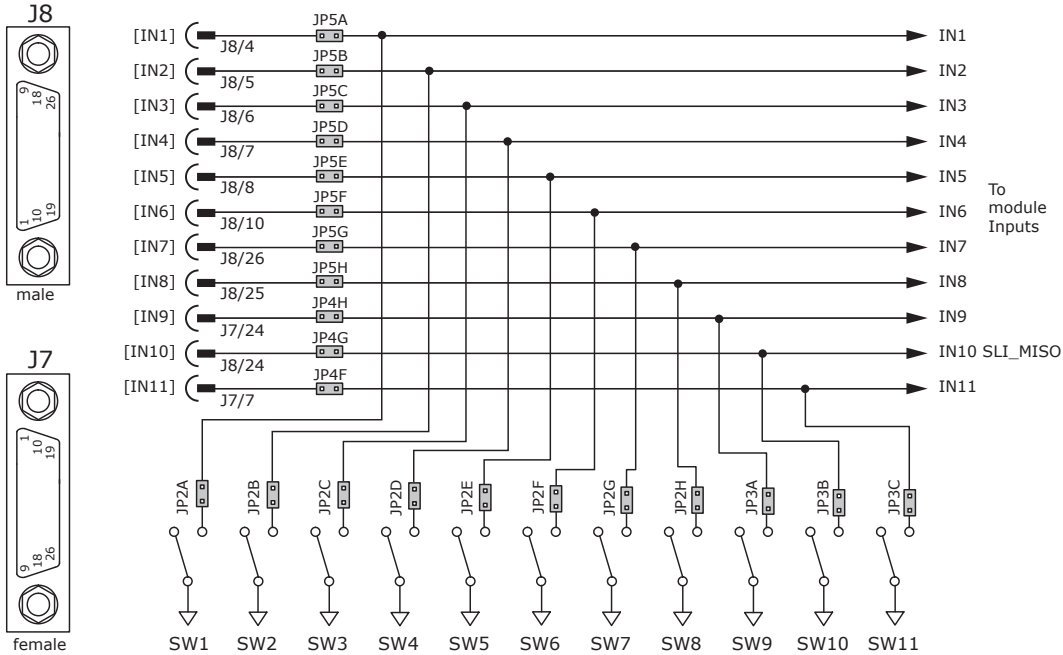
## LOGIC OUTPUTS

There are six logic outputs that can drive controller logic inputs or relays. If relays are driven, then flyback diodes must be connected across their terminals to clamp overvoltages that occur when the inductance of the relay coil is suddenly turned off. Outputs 3,4,5 & 6 are CMOS types that pull up to 5V or down to ground. When these outputs go high it turns on the green LED. When they are low, the red LED is turned on. Outputs 1 & 2 are MOSFET types that sink current when ON, and appear as open-circuit when OFF. When these outputs are ON a red LED is turned on. When the outputs are OFF, the red LED is off. The green LED is not used on these outputs.
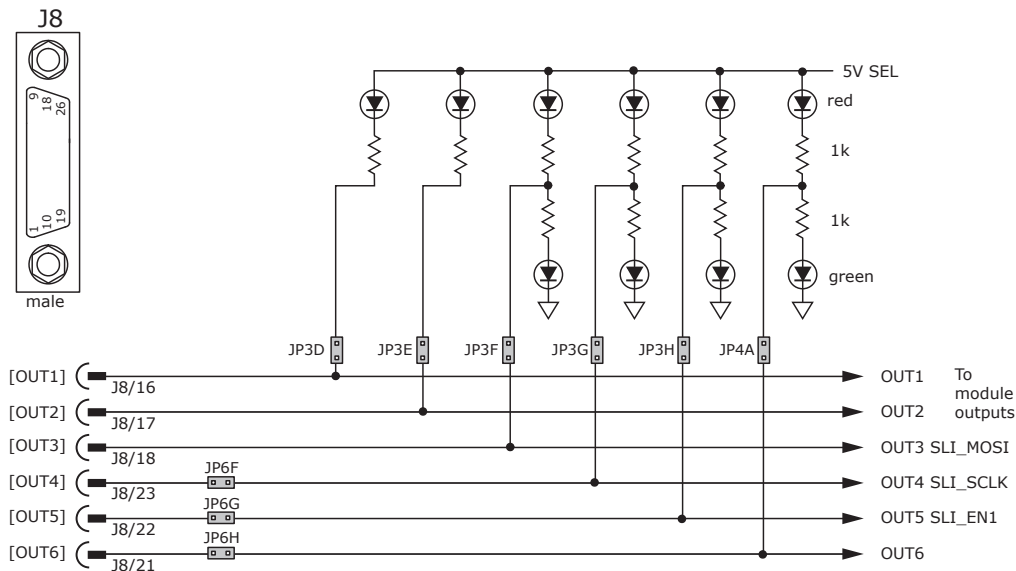
## MOTOR FEEDBACK CONNECTOR J7

For motors with differential encoders: install jumpers JP1B, JP1D, JP1F, and JP1H to connect 121 ohm terminators across inputs
Jumpers JP1A, JP1C, JP1E, and JP1G do not affect this setting and may remain in place or be removed.

For motors with single-ended encoders: remove jumpers JP1B, JP1D, JP1F, and JP1H to disconnect 121 ohm terminators
Install jumpers JP1A, JP1C, JP1E, and JP1G

A motor temperature sensor that connects to [IN11] must have jumper JP4F installed and JP3C removed to prevent switch SW11 from grounding the Motemp[IN11] signal.

If the encoder has a fault output, then jumper JP4H must be in place and jumper JP3A must be removed to prevent switch SW9 from grounding the Enc Fault [IN9] signal.

Absolute encoders such as the Nikon A type that use 2-wire bidirectional signals require biasing the lines when they are in a quiescent state. Jumpers JP1G, JP1H, and JP6A must be in place to provide line termination and biasing.

LED's are provided to show the status of the encoder and Hall signals.
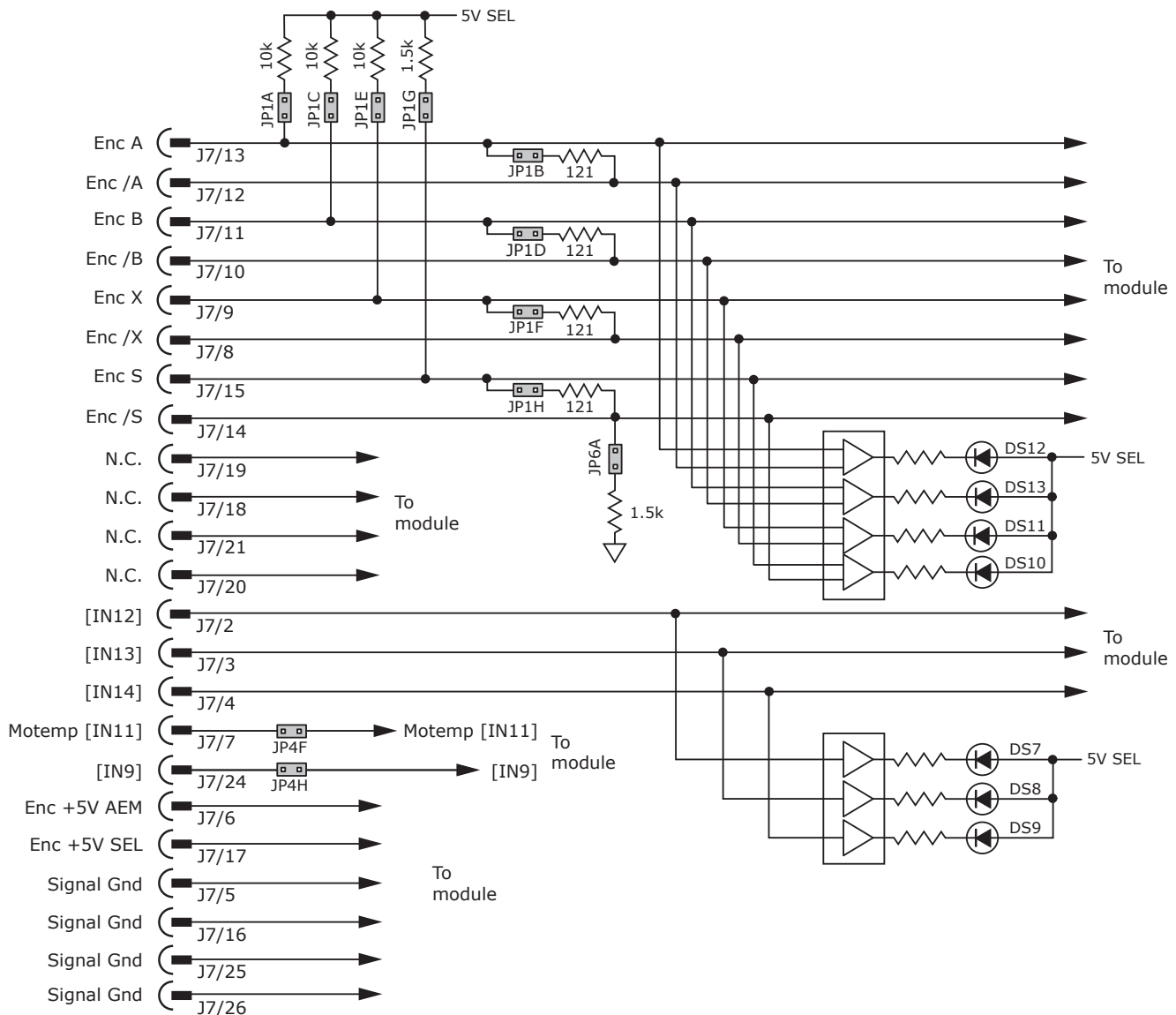
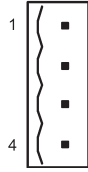## DEVELOPMENT KIT CONNECTIONS
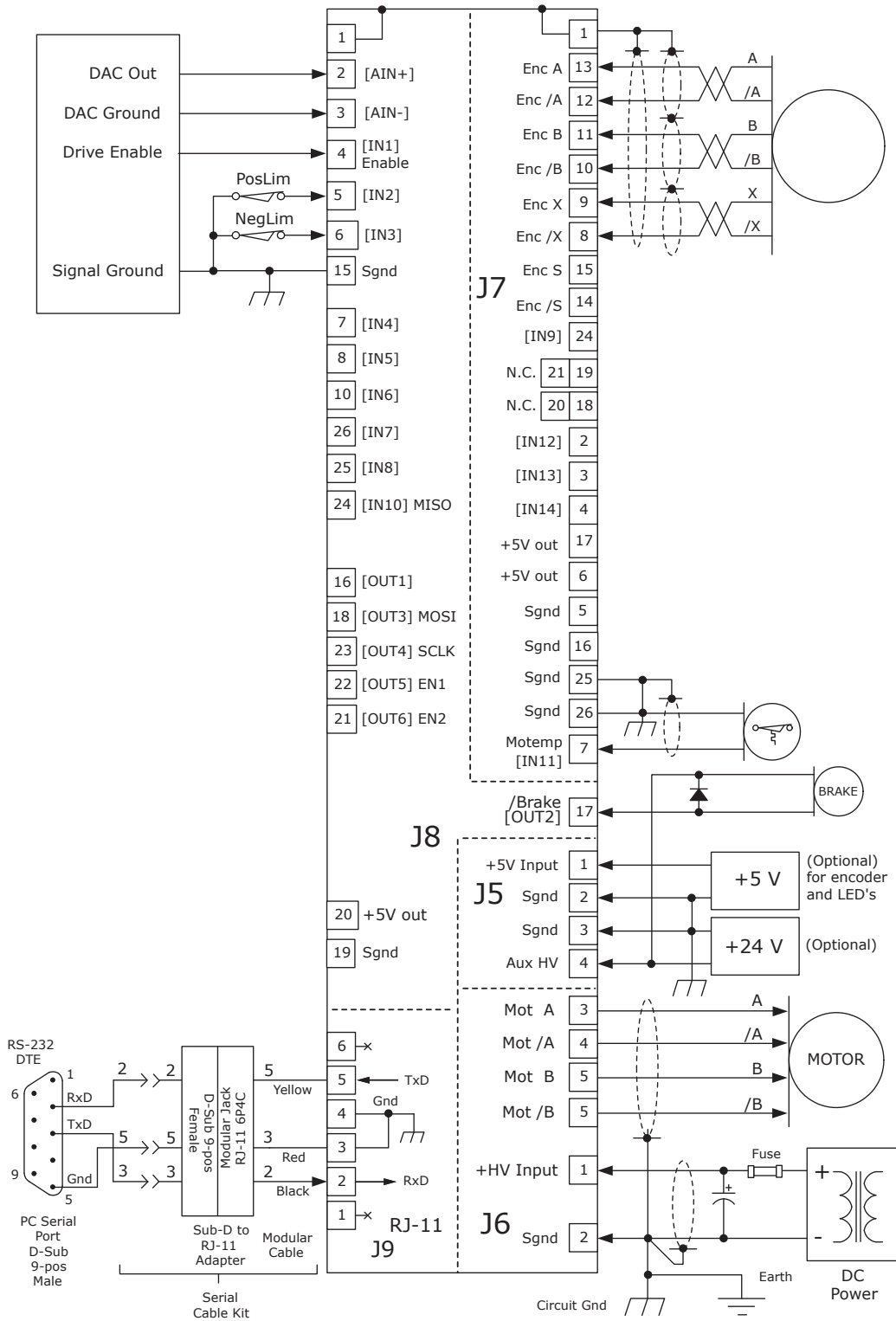


**Notes:**
1. EtherCAT connectors J10 are not shown here. For details see pp 4 & 13.

## DEVELOPMENT KIT

The Development Kit mounts a single SEM module and enables the user to test and operate the SEM before it is mounted onto a PC board in the target system.
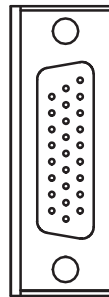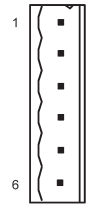
### J6 AUX HV & EXT 5V

| Signal | Pin |
|--------|-----|
| +5V Ext | 1 |
| Sgnd | 2 |
| Sgnd | 3 |
| Aux HV Input | 4 |

### J6 MOTOR

| Signal | Pin |
|--------|-----|
| +HV Input | 1 |
| HV Gnd | 2 |
| Motor A | 3 |
| Motor /A | 4 |
| Motor B | 5 |
| Motor /B | 6 |

**J5** HV & Aux

**J6** Motor
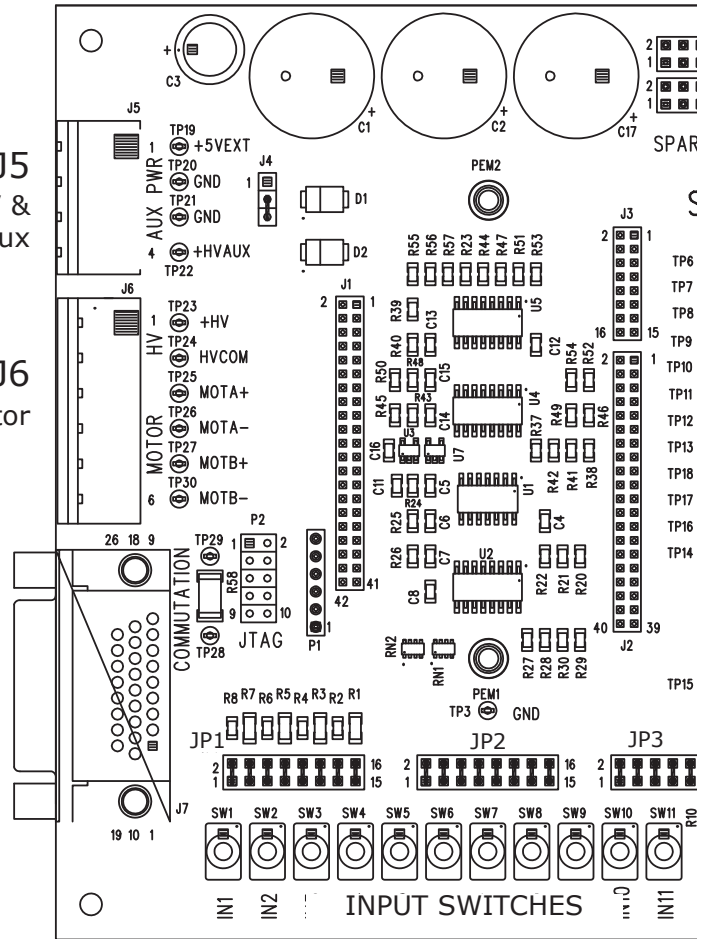
**J7** Feedback

### J7 FEEDBACK

| PIN | SIGNAL | PIN | SIGNAL | PIN | SIGNAL |
|-----|--------|-----|--------|-----|--------|
| 26 | Sgnd | 18 | N.C. | 9 | Enc X1 |
| 25 | Sgnd | 17 | +5 Vdc Out | 8 | Enc /X1 |
| 24 | [IN9]Enc Fault | 16 | Sgnd | 7 | [IN11] Motemp |
| 23 | N.C. | 15 | Enc S1 | 6 | +5 Vdc Out |
| 22 | N.C. | 14 | Enc /S1 | 5 | Sgnd |
| 21 | N.C. | 13 | Enc A1 | 4 | [IN14] |
| 20 | N.C. | 12 | Enc /A1 | 3 | [IN13] |
| 19 | N.C. | 11 | Enc B1 | 2 | [IN12] |
|  |  | 10 | Enc /B1 | 1 | Frame Gnd |

Copley Controls, 20 Dan Road, Canton, MA 02021, USA

Web: www.copleycontrols.com

Tel: 781-828-8090

Fax: 781-828-6547

16-01588 Rev 00

Page 21 of 26

Device ID-SWITCHES

### J10 ETHERCAT

| Pin | Signal |
|-----|--------|
| 1   | TX+    |
| 2   | TX-    |
| 3   | RX+    |
| 6   | RX-    |

### J9 RS-232

| Pin | Signal |
|-----|--------|
| 1   | n.c.   |
| 2   | RxD    |
| 3   | Sgnd   |
| 4   | Sgnd   |
| 5   | Txd    |
| 6   | n.c.   |
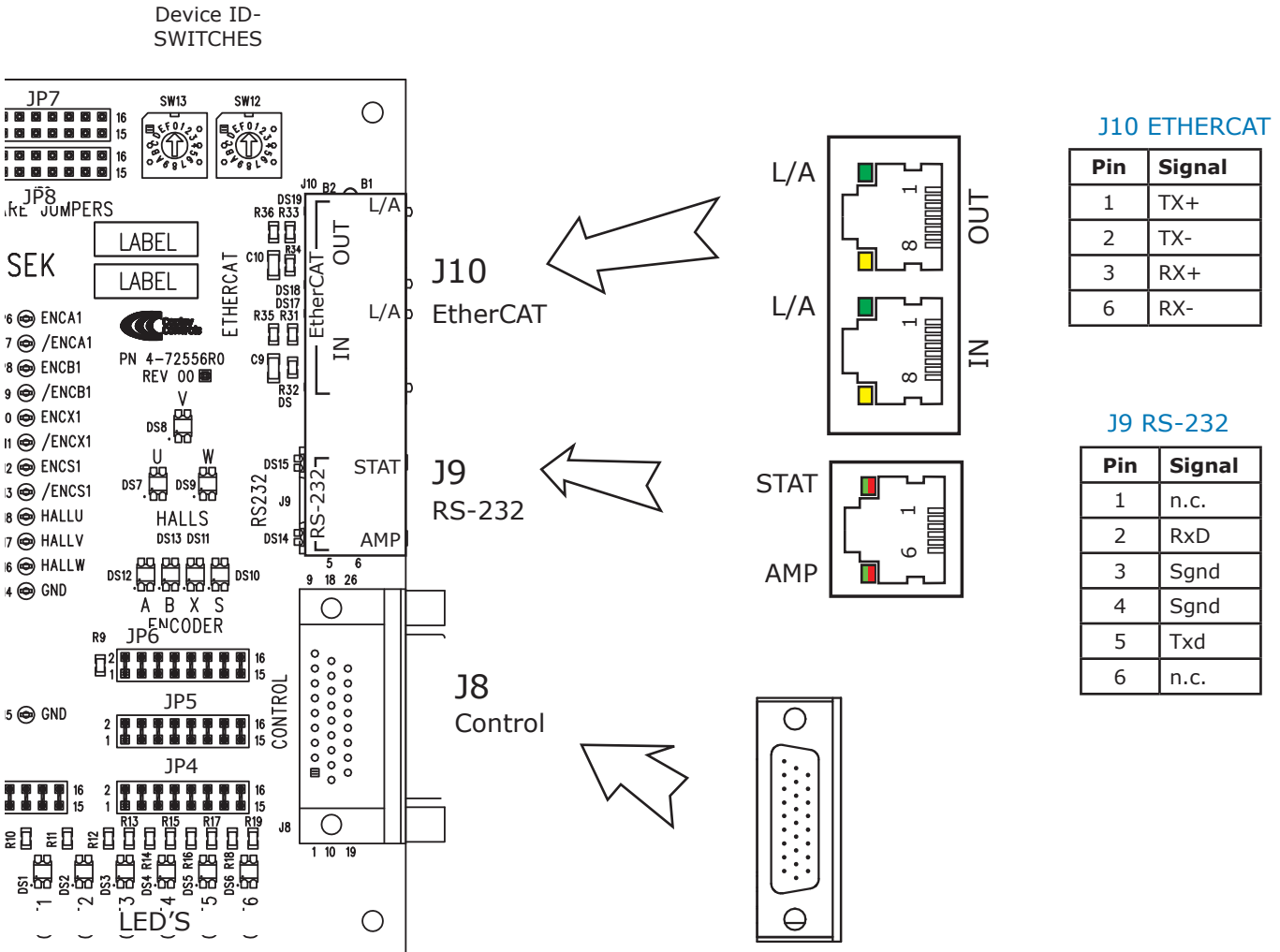
### J8 CONTROL

| PIN | SIGNAL | PIN | SIGNAL | PIN | SIGNAL |
|-----|--------|-----|--------|-----|--------|
| 9 | N.C. | 18 | [OUT3] MOSI | | |
| 8 | [IN5] HS | 17 | [OUT2] GP | PIN | SIGNAL |
| 7 | [IN4] HS | 16 | [OUT1] GP | 26 | [IN7] HS |
| 6 | [IN3] HS | 15 | Sgnd | 25 | [IN8] HS |
| 5 | [IN2] HS | 14 | N.C. | 24 | [IN10] MISO |
| 4 | [IN1] HS | 13 | N.C. | 23 | [OUT4] CLK |
| 3 | [AIN1-] | 12 | N.C. | 22 | [OUT5] EN1 |
| 2 | [AIN1+] | 11 | N.C. | 21 | [OUT6] EN2 |
| 1 | Frame Gnd | 10 | [IN6] HS | 20 | +5 Vdc Out |
| | | | | 19 | Sgnd |

## POWER DISSIPATION

The charts on this page show the drive's internal power dissipation for different models under differing power supply and output current conditions. Drive output current is calculated from the motion profile, motor, and load conditions. The values on the chart represent the rms (root-mean-square) current that the drive would provide during operation. The +HV values are for the average DC voltage of the drive power supply.

To see if a heatsink is required or not, the next step is to determine the temperature rise the drive will experience when it's installed. For example, if the ambient temperature in the drive enclosure is 40 °C, and the heatplate temperature is to be limited to 70° C or less to avoid shutdown, the maximum rise would be 70C - 40C. or 30° C. Dividing this dissipation by the thermal resistance of 9º C/W with no heatsink gives a dissipation of 3.33W. This line is shown in the charts. For power dissipation below this line, no heatsink is required. The vertical dashed lines show the continuous current ratings for the drive modelsv.



Continuous Output Current (Adc)
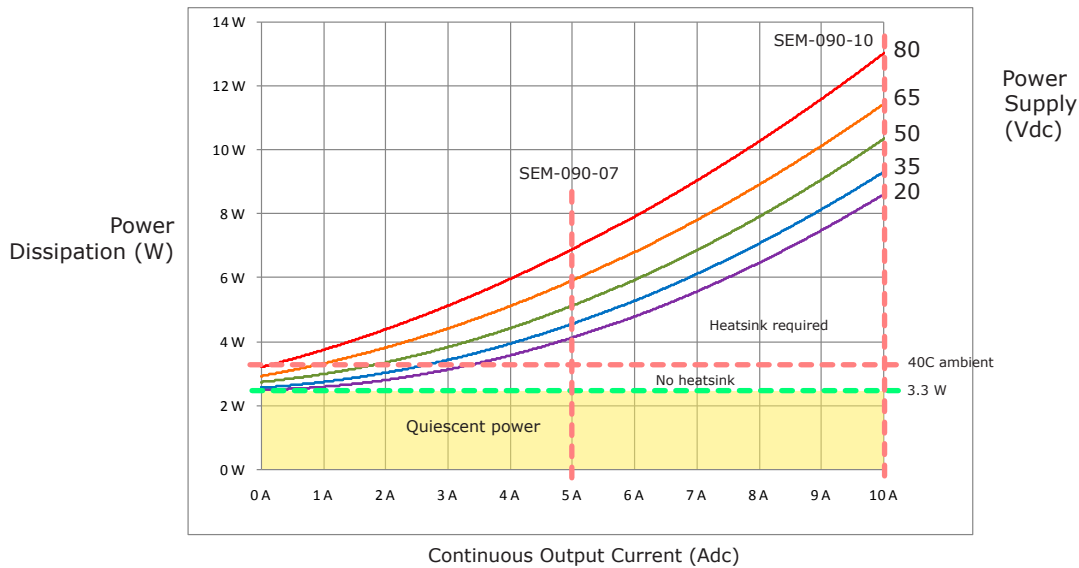
## HEATSINK INSTALLATION USING THE SEM-HK HEATSINK KIT

An AOS Micro Faze thermal pad is used in place of thermal grease. This material comes in sheet form and changes from solid to liquid form as the drive warms up. This forms an excellent thermal path from drive heatplate to heatsink for optimum heat transfer.

### STEPS TO INSTALL

1. Remove the thermal pad from the clear plastic carrier.

2. Place the thermal pad on the *Stepnet* aluminum heatplate taking care to center the thermal pad holes over the holes in the drive body.

3. Mount the heatsink onto the thermal pad again taking care to see that the holes in the heatsink, thermal pad, and drive all line up.

4. Torque the #4-40 mounting screws to 3~5 lb-in (0.34~0.57 N·m).



#4-40 Mounting Screws

Thermal Pad

Heatsink

Transparent Carrier (Discard)

*SEM* Drive
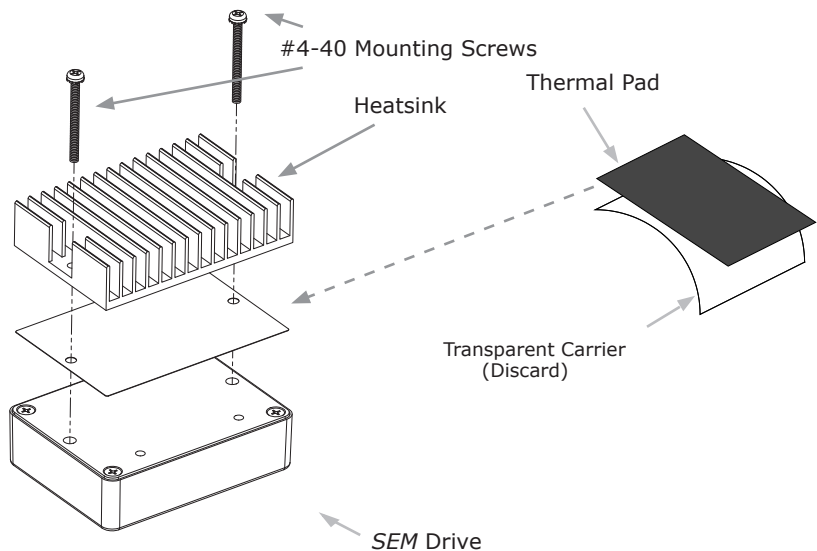
## HEATSINK OPTIONS

Rth expresses the rise in temperature of the drive per Watt of internal power loss. The units of Rth are °C/W, where the °C represent the rise above ambient in degrees Celsius. The data below show thermal resistances under convection, or fan-cooled conditions for the no-heatsink, and SEM-HS heatsink.

### NO HEATSINK

| NO HEATSINK | C/W |
|---|---|
| CONVECTION | 9.1 |
| FORCED AIR (300 LFM) | 3.3 |

### STANDARD HEATSINK (SEM-HK)
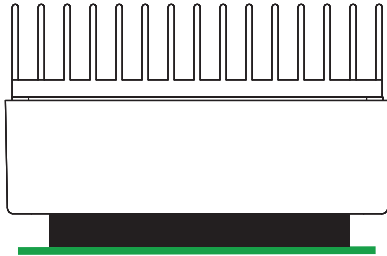
| WITH HEATSINK | C/W |
|---|---|
| CONVECTION | 5.3 |
| FORCED AIR (300 LFM) | 1.1 |

**THIS PAGE
LEFT BLANK
INTENTIONALLY**

## MASTER ORDERING GUIDE

| | |
|---|---|
| SEM-090-07 | *Stepnet* SEM stepper drive, 5/7 A, 20~90 Vdc |
| SEM-090-10 | *Stepnet* SEM stepper drive, 10/10 A, 20~90 Vdc |
| SEK-090-01 | Development Kit for SEM stepper drive |

## ACCESSORIES

| | QTY | DESCRIPTION |
|---|---|---|
| Connector Kit for Development Kit SEK-CK-01 | 1 | Connector, Euro, 5 Terminal, 5.08 mm |
| | 1 | Connector, Euro, 4 Terminal, 5.08 mm |
| | 1 | 26 Pin Connector, High Density, D-Sub, Male, Solder Cup |
| | 1 | 26 Pin Connector, High Density, D-Sub, Female, Solder Cup |
| | 2 | 26 Pin Connector Backshell |
| Heatsink Kit SEM-HK | 1 | Heatsink for SEM |
| | 1 | Heatsink Thermal Pad |
| | 2 | Screws, #4/40 x 1.25", SEMS |
| SEK-NC-10 | | Ethernet Network Cable, 10 ft |
| SEK-NC-01 | | Ethernet network cable, 1 ft |
| CME 2 | | CME 2 Drive Configuration Software on CD-ROM |
| SER-CK | | Serial Cable Kit for Development Kit |

EtherCAT is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Note: Specifications subject to change without notice