Pedal Controlled Application User Manual For Azure Dynamics DMOC Motor Controller

MAN-080002-001 DECEMBER 2009

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Table of Contents

Forward

Caution

The information provided in this manual is intended for use by persons with appropriate technical skills. Any effort to perform repairs to or service your unit without the proper tools or knowledge required for the work can result in personal injury and product damage and will void your warranty!

Contact Information

Please feel free to call with any suggestions that you may have regarding the content of your manual. If additional service information is needed or to order replacement parts, please call Monday–Friday 8:30AM–5:30PM USA Eastern Time:

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How to Report Errors

If, while reading through this manual, you discover an error in the technical information provided, Azure Dynamics asks that you notify its Product Support Department. Please be prepared to provide the following information:

- Your name
- Name and edition of your manual
- Page number(s) where the error(s) appear
- Part number and serial number of your unit

Information contained in this manual is based on the latest product information available at the time of publication. The right is reserved to make changes at any time without notice.

Safety

For your safety and the safety of others, please read and understand this entire manual before installing the components you have received from Azure Dynamics. If you have questions regarding the contents of this manual, please call the Azure Dynamics Product Support Department before proceeding.

Warning Labels

Labels indicate areas in a procedure where you should take appropriate precautions. Labels include:

WARNING AND DANGER

RISK OF ELECTRIC SHOCK

Safety Symbols

Always use caution when working on or around any electrical equipment. Wear eye protection at all times. The following symbols will be located in your manual to indicate sections in a procedure where extra caution and/or safety equipment is required.

HEARING PROTECTION REQUIRED

EYE PROTECTION REQUIRED

Always follow any safety instructions that are given at the beginning of a procedure. If you are uncertain as to the safe and proper handling of your equipment, contact Azure Dynamics Product Support.

Overview

The Azure Dynamics Digital Motor Controller (DMOC445 or DMOC645) is a rugged traction inverter for controlling three-phase AC motors and generators. Flexible software architecture allows for application-specific customization by loading software application modules. These application modules communicate with the motor control core and implement the interface to the higher level controls or directly to the driver inputs and outputs.

This manual discusses the “Pedal Controlled” application layer which configures the DMOC to function as a stand-alone traction controller for vehicular applications. In combination with a “DMOC Interface Kit” this application module offers all the functionality for implementing a complete electric vehicle drive. Features include:

- Accelerator pedal mapping with detection of short or disconnected wire
- Electrical braking with:
  anti-reverse
  disable switch
  battery protections
  brake light control
- Forward/reverse/neutral gear selection
- Three-level power selection
- Status reporting over CAN (new “FRC” software only)

For general information regarding the DMOC, including important safety instructions and warnings, the DMOC445 and DMOC645 User Manual should be consulted which is distributed and revised separately. See Table 1 for the list of relevant manuals.

Azure’s PC-based diagnostics/calibration tool ccShell allows the user to access and modify DMOC calibration parameters and to visualize and capture signals and variables in real time. (Calibration parameters have EE1, EE2 or EEX prefixes. Variables have EE3, ISR or FRC prefixes). While the meanings of the most important calibrations and signals of the DMOC core are described in this document, the reader is referred to the ccShell User Manual for information on how to install and use this tool.

Table 1: List of Relevant Manuals

Document Name	Document Number
DMOC445 and DMOC645 User Manual	MAN-080001
Pedal Controller Application User Manual	MAN-080002
CAN Controlled Application User Manual	MAN-080003
ccShell User Manual Please note, this manual is distributed as part of the ccShell software. It is available under ccShell’s “Help” menu.)	MAN-080008

Application Software

Pedal Map

The accelerator pedal position is mapped to a desired torque as described here. The map itself is configurable by parameter calibration. Three valid zones can be distinguished (for better readability, the EEX parameter prefixes of the parameter names are omitted in Figure 1):

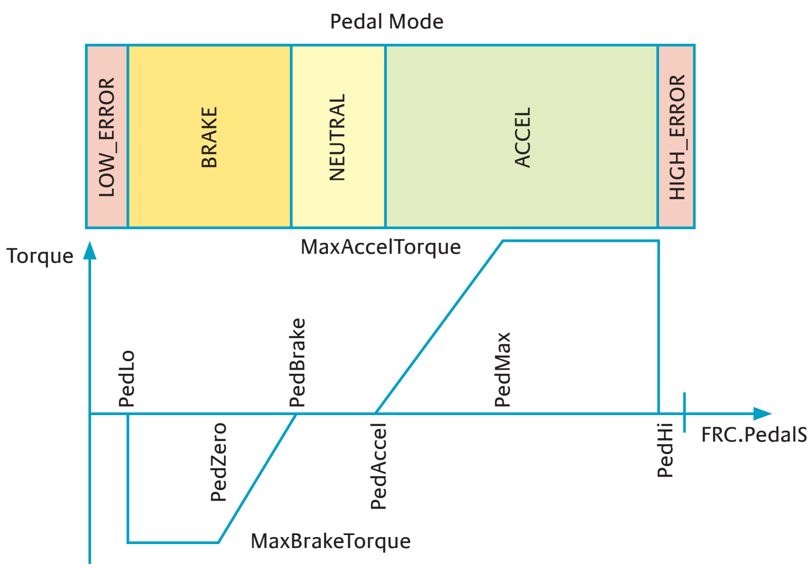


Figure 1: Pedal Torque Map

Fault Zones: The red zones indicate fault zones. If the pedal input is shorted, high or low, zero torque is produced. Any pedal values below PedLo (hard coded at 0.01) or above PedHi (hard coded at 0.9) are consider to be a pedal fault (short or open) and will result in no torque.

Brake Zone: The first zone of the pedal is used to control regenerative braking. It ranges from PedLo (fixed) to EEXPedBrake. Full torque (EEXMaxBrakeTorque) is applied when the accelerator pedal is not depressed at all. As the pedal is depressed past EEXPedZero, the brake torque is ramped down linearly.

Coast or Neutral Zone: The torque is zero in the second zone, which is delimited by EEXPedBrake and EEXPedAccel.

Accel Zone: Past EEXPedAccel, the torque is ramped up as the pedal is depressed. The torque reaches its maximum value (EEXMaxAccelTorque) at EEXPedMax.

Table 2 summarizes the variable FRC.PedMode.

Table 2: FRC.PedMode Variable

Variable:	FRC.PedMode	
State Value	Name	Description
0	NEUTRAL	Vehicle is in neutral or pedal position is in coast zone
1	ACCEL	Vehicle is in FWD or REV and pedal position is in accel zone
2	BRAKE	Vehicle is in FWD or REV and pedal position is in brake zone
3	*reserved*	
4	LOW_ERROR	Pedal is shorted to GND
5	HIGH_ERROR	Pedal is shorted to +Vcc

In some vehicles, a strong feedback between the vehicle's motion and the driver's foot exists. It can lead to unwanted oscillations and may cause serious drivability problems. An effective method to break the resonance is to add a dead band to the position sensing; this is illustrated in Figure 2. If the driver's foot oscillates within the dead band, no change in the measured pedal position is made and the drive torque remains constant. The position of the pedal can be viewed by means of the variable FRC.PedalS. The pedal position FRC.PedalS is a normalized variable (0-1) derived from the voltage of the 5kΩ pedal potentiometer. The pedal map parameters are listed in Table 3.

Table 3: Pedal Map Parameters

Parameter	Description
EEXMaxAccelTorque	Maximum acceleration torque when pedal is fully depressed
EEXMaxBrakeTorque	Maximum braking torque when pedal is fully released
EEXPedBrake	Pedal value below which braking torque begins to be applied
EEXPedZero	Pedal value below which max braking torque (EEXMaxBrakeTorque) is applied
EEXPedAccel	Pedal value above which acceleration torque begins to be applied
EEXPedMax	Pedal value above which max acceleration torque (EEXMaxAccelTorque) is applied
EEXPedHyst	Hysteresis value for pedal input (pedal position needs to change by more than EEXPedHyst to be recognized as a valid new position)

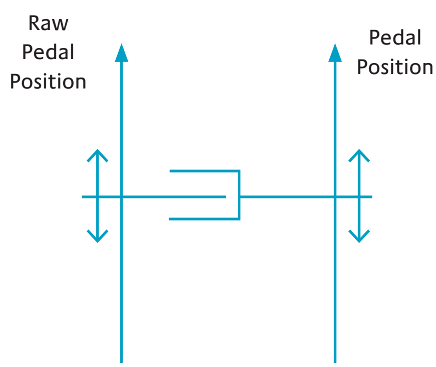


Figure 2: Pedal Dead Band

Applications That Do Not Use a 5kΩ Pedal Pot

Figure 3 and Figure 4 below are provided as a reference for applications that do not use a 5kΩ pedal pot. The circuit schematic in Figure 3 shows the pullup and pulldown resistors (inside the DMOC) that are associated with the PEDAL_HI and PEDAL_LOW outputs. Note that VCC_A is 3.3V. The circuit schematic in Figure 4 shows that the ACCEL_PEDAL input of the DMOC is pulled down to “ground” by a 100kΩ resistor, and the signal then passes through a unity gain buffer. Please note, though these schematics are accurate as of this writing, they are subject to change and therefore should be used for reference only.

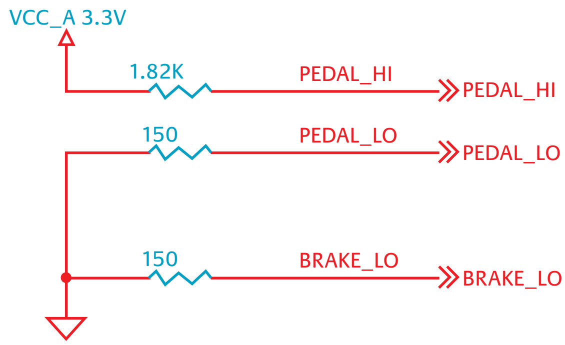


Figure 3: Pullup/pulldown resistors inside DMOC associated with PEDAL_HI/PEDAL_LOW outputs.

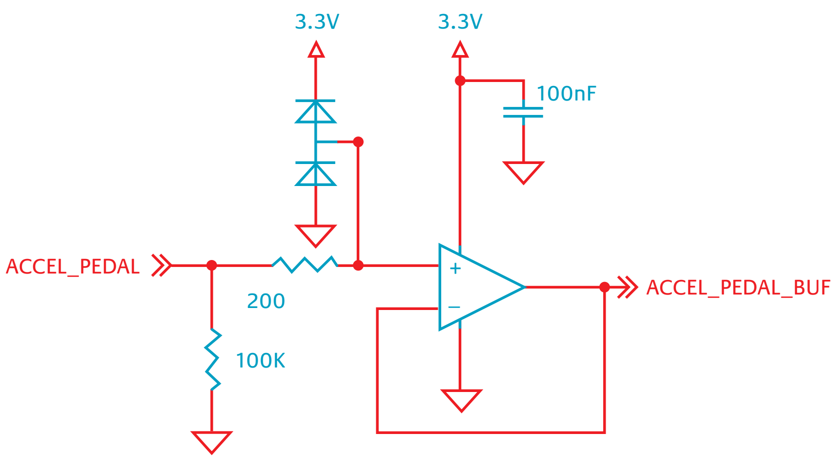


Figure 4: ACCEL_PEDAL input of DMOC pulled to “ground” by 100kΩ resistor, then passed through unity gain buffer.

Speed Ramps

Several ramps are implemented to reduce and limit the drive torque corresponding to vehicle speed. These ramps prevent the vehicle from over speeding, both in reverse (for safety) and in forward (for motor protection). The overspeed protection ramps are illustrated in Figure 5. The acceleration parameters are listed in Table 4.

During regenerative braking, the brake torque must be reduced to zero before the vehicle starts reversing its direction. These ramps are illustrated in Figure 6. Similar to the pedal map, the speed ramps are configurable by means of parameter calibration; the parameters themselves are listed in Table 5.

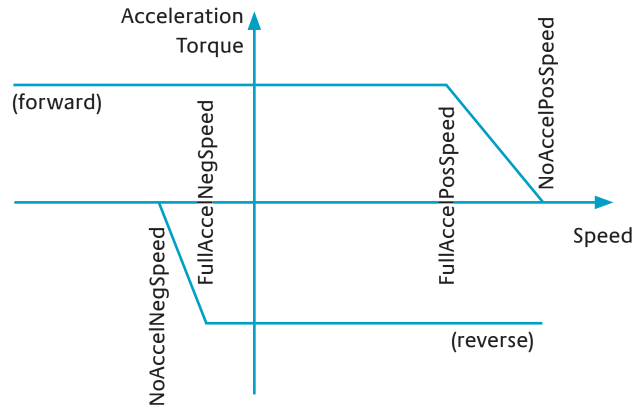


Figure 5: Speed Ramps under Acceleration

Table 4: Acceleration Parameters

Parameter	Description
EEXFullAccelPosSpeed	Positive (forward) motor speed up to which full acceleration torque (EEXMaxAccelTorque) is allowed
EEXNoAccelPosSpeed	Positive (forward) motor speed above which acceleration torque is zero
EEXFullAccelNegSpeed	Negative (reverse) motor speed up to which full acceleration torque (EEXMaxAccelTorque) is allowed
EEXNoAccelNegSpeed	Negative (reverse) motor speed above which acceleration torque is zero

Note: Torque is linearly ramped between EEXFullAccelPosSpeed and EEXNoAccelPosSpeed, and between EEXFullAccelNegSpeed and EEXNoAccelNegSpeed.

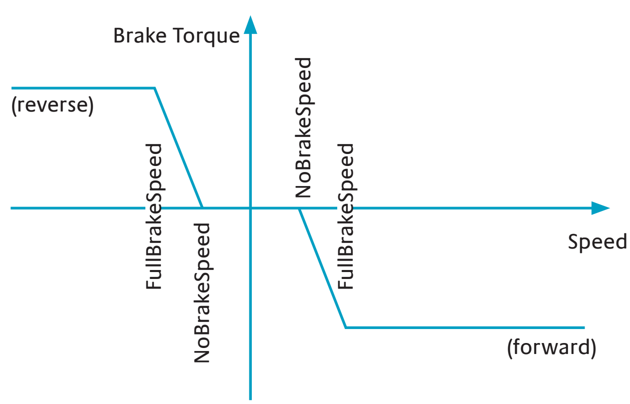


Figure 6: Speed Ramps When Braking

In order to avoid oscillations around the EEXNoBrakeSpeed point, a hysteretic loop is implemented as shown in Figure 7. The parameters are listed in Table 5. As the vehicle slows down under regenerative braking past EEXFullBrakeSpeed, the torque is reduced linearly with speed. Once the vehicle speed drops below EEXNoBrakeSpeed, regenerative braking is completely disabled, until the vehicle re-accelerates past EEXRegenOnSpeed. This method has proven to be successful in avoiding brake torque oscillations at very low speeds. The regen state variable, FRC.RegenState takes the values in Table 6 and can be viewed with ccShell.

Table 5: Regen Parameters

Parameter	Description
EEXFullBrakeSpeed	Motor speed (both positive and negative) above which full braking torque (EEXMaxBrakeTorque) is applied.
EEXNoBrakeSpeed	Motor speed (both positive and negative) below which regen braking is completely disabled
EEXRegenOnSpeed	Motor speed (both positive and negative) above which regen braking is re-enabled

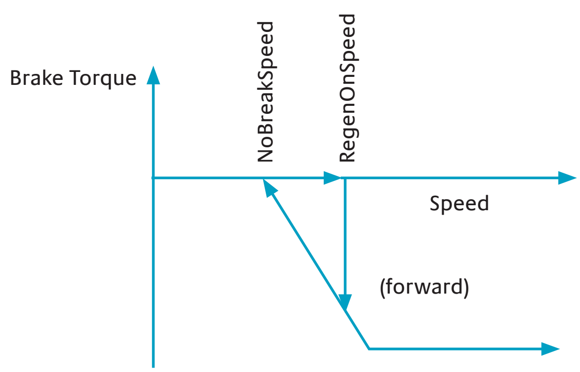


Figure 7: Hysteretic Loop around EEXNoBrakeSpeed

Table 6: Regen State Values

Variable:	FRC.RegenState (formally called ISR2RegenState)	
State	Name	Description
0	POWERUP	Regenerative braking feature not yet initialized
1	DISABLED	Regenerative braking feature is disabled
2	ENABLED	Regenerative braking feature is enabled
3	FAULT	Regenerative braking feature has a problem

Torque Slew Rate Limiting

To improve drivability, it is necessary to limit the rate of change of the motor torque (also known as slew rate). The application software provides several parameters to tune the slew rates as shown in Table 7.

Table 7: Slew Rate Parameters

Parameter	Description
EEXTorqueSlew	Slew rate limit on torque set point in acceleration mode
EEXBrakeTorqueSlew	Slew rate limit on torque set point in braking mode
EEXUnloadSlew	Slew rate when reducing torque while preserving torque sign

Specific positive and negative slew rates are applied based on the torque level (divided into four zones) as shown in Table 8.

Table 8: Torque Slew Rate Parameters Logic

Initial Torque Value	Increasing Torque	Decreasing Torque
EEXPreloadTorque < Torque	EEXTorqueSlew	EEXUnloadSlew
0 < Torque < EEXPreloadTorque	EEXTorqueSlew	EEXTorqueSlew
-EEXPreloadTorque < Torque < 0	EEXBrakeTorqueSlew	EEXBrakeTorqueSlew
Torque < -EEXPreloadTorque	EEXBrakeTorqueSlew	EEXUnloadSlew

A graphic representation of the torque slew rate limits is shown in Figure 8.

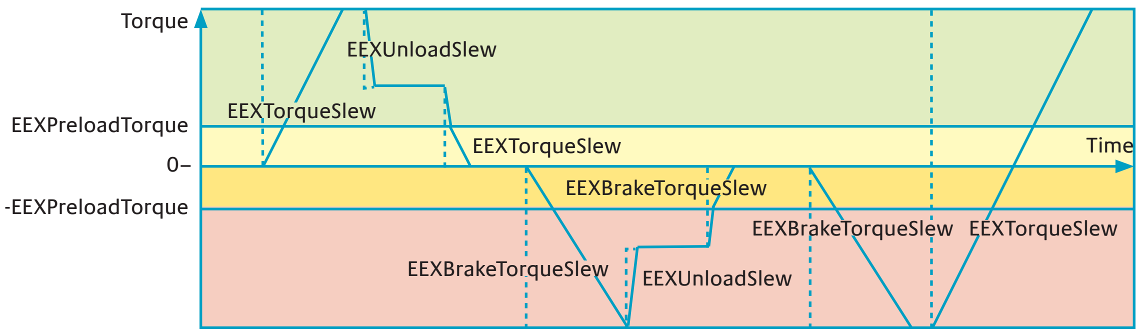


Figure 8: Torque Slew Rate Limits

Power Saver Selector

The battery power limit for acceleration is selectable by means of the “Tri-Power Switch” (part of the optional “DMOC Interface Kit”) which is connected to the “Power Saver” input. The “Power Saver” is an analog input mapped into three zones, as depicted in Figure 9. The power level is determined based on the user input resistance Rp and the threshold values R1 and R2 discussed further below. Note that the resistance with key off for Econ (max range) must be less than the resistance with key off for Normal, which must be less than the resistance with key off for Power (max power). In most circumstances, especially if the customer is using Azure’s DMOC interface kit, no adjustment will be necessary.

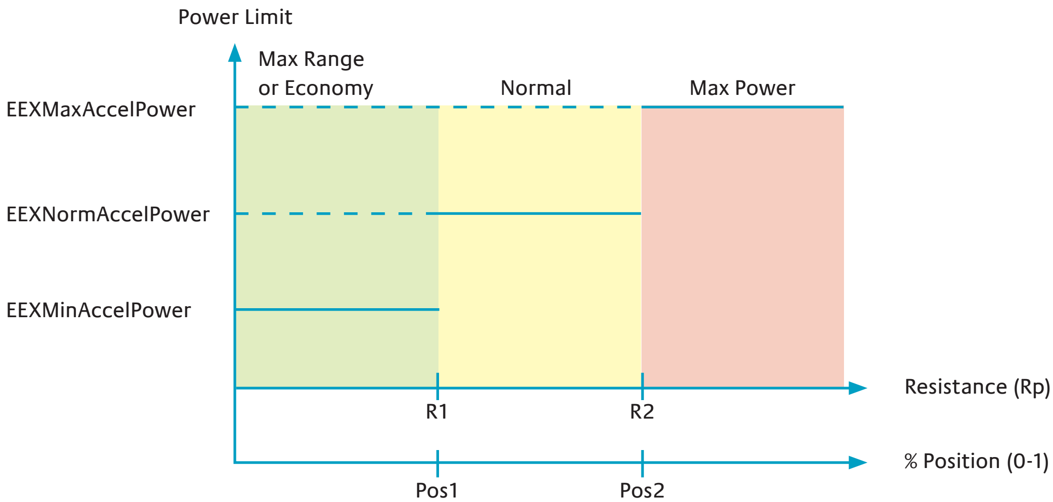


Figure 9: Power Saver Zones, based on power saver resistance input

The Power level is determined by the resistance provided across the power saver input, as shown in Figure 10. The equation for the voltage divider circuit for the power saver potentiometer is:

$$\frac{Rp}{(Rp + 5K\Omega)} = \text{Position (0-1,normalized \%)}$$

where Rp is the resistance across the power saver switch (i.e. the user input across pins 15 and 16 of the DMOC 35-pin connector).

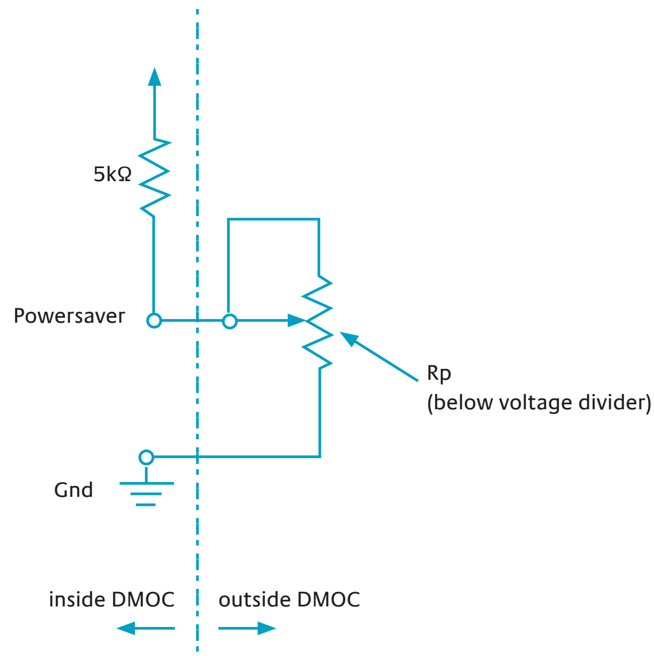


Figure 10: Voltage Divider Circuit for Power Saver Potentiometer

The Power Saver zones are shown in Table 9, and the power levels can be adjusted by the calibrations there.

Table 9: Power Saver Zones

Variable:	FRC.PowerSaverSel	
State	Name	Description
1	MAX_POWER	EEXMaxAccelPower is the selected power limit
2	NORM_POWER	EEXNormAccelPower is the selected power limit
3	MIN_POWER	EEXMinAccelPower is the selected power limit

Power Saver Thresholds:

The zone thresholds (R1 and R2 in Figure 9) default to 3.8kΩ and 8.15 kΩ, respectively.

The resistance across the power saver input (pins 15 and 16 on the DMOC 35-pin connector) determines the power saver setting as follows:

Max Range:	Rp <	3.8 kΩ		
Normal:		3.8 kΩ	< Rp <	8.15 kΩ
Max Power:				8.15 kΩ <Rp

These thresholds are not adjustable in software released before April 2008 (including “1631”).

Adjustable Zone Thresholds:

The adjustable zone thresholds are a new feature implemented in the "FRC" software release, starting in April 2008. The zone thresholds are controlled via calibration of the parameters in Table 10. Calibration instructions are below.

Table 10: Power Saver Calibration

Parameter	Description
EEXPowerSaverPos1	Below this threshold the PowerSaver mode is MIN_POWER
EEXPowerSaverPos2	Above this threshold the PowerSaver mode is MAX_POWER

Adjusting Tri-Power Switch Resistances in "FRC" Software

In FRC software, if the default resistances for the tri-power switch thresholds are incorrect for your application, they can be adjusted in software using ccShell, based on position (ISR1PowerSaver).

The two ccShell parameters involved are EEXPowerSaverPos1 and EEXPowerSaverPos2. The default values for EEXPowerSaverPos1 and EEXPowerSaverPos2 are 0.42969 and 0.61914, respectively (corresponding to the default resistances specified above).

Example of correction if the resistances are not within the ranges above, for FRC software only:

<table>
<tr><th>Tri-power switch setting</th><th>Measure key off resistance (Rp)</th><th>Calculate Rp ÷ (Rp + 5kΩ)</th><th>Change EEXPowerSaverPos1</th><th>Change EEXPowerSaverPos2</th></tr>
<tr><td>Econ (max range)</td><td>1.56 kΩ</td><td>0.24</td><td rowspan="2">currently 0.42969, needs to be between 0.24 and 0.31</td><td></td></tr>
<tr><td>Normal</td><td>2.29 kΩ</td><td>0.31</td><td rowspan="2">currently 0.61914, needs to be between 0.31 and 0.52</td></tr>
<tr><td>Power (max power)</td><td>5.42 kΩ</td><td>0.52</td><td></td></tr>
</table>

Safety & Interlocks

Shutdown/Disconnect

For a shutoff, it is recommended that the 12V be disconnected. Removing the 12V power will immediately disable the DMOC power supply and shut the unit down. For additional safety, it is recommended that an emergency high voltage disconnect be provided as well; however, this should be a normally closed switch that is only actuated in emergencies or for maintenance. If a contactor is used as a HV disconnect, it could interfere with the operation of the DMOC's internal contactor, resulting in excessively long precharge times, or damage the DMOC.

Interlocks

At power up, the DMOC will remain disabled as long as either the accelerator pedal is depressed or the gear switch is in forward or reverse. This is a startup safety interlock; you must have zero torque request and be in neutral for the DMOC to power up and enable.

Startup order of operation/sequence:

- Contactor must close
- Powerstage must advance to READY

For these events to occur there are a few application—specific interlocks described here, which are required in addition to the requirements documented in the DMOC445 and DMOC645 User Manual:

Contactor Interlock:

- ISR2DriveEnabled = TRUE (or bypass with EEXNoIgnSwitch, see below), and
- FRC.CarDirectionSwitch = NEUTRAL

Power Stage Interlocks Required for READY, indicated by ISR2PowerStageStateInfo = WAITING_FOR_APPLICATION_CODE_INTERLOCK:

- Pedal not depressed (Pedal position less than EEXPedZero).

Power Stage Fault acknowledge interlock, indicated by ISR2PowerStageStateInfo = WAITING_FOR_FAULT_ACKNOWLEDGE

- Pedal not depressed (Pedal position less than EEXPedZero), and
- No torque is requested.

To command torque and spin the motor

FRC.CarDirectionSwitch = FORWARD or REVERSE

Pedal depressed (Pedal position more than EEXPedAccel).

The DMOC also has a "drive enable" and a "drive disable" signal (digital inputs) which are both active low (i.e. need to be pulled to GND to be active). For the DMOC to enable, drive enable has to be active and drive disable needs to be passive (i.e. not pulled to GND). If the "drive enable" feature is not desired, it can be switched off by setting the calibration parameter EEXNoIgnSwitch to 1. Grounding "drive disable" will always result in disabling the DMOC; this is often used as a charger interlock.

Table 11: Drive Enable-Disable Parameter

Parameter	Description
EEXNoIgnSwitch	0 = ISR2DriveEnabled depends on "drive enable" 1 = ISR2DriveEnabled=TRUE ("drive enable" ignored)

Principal Application Variables

Table 12 shows the most frequently viewed application variables. Refer to the DMOC445 and DMOC645 User Manual for information about other important DMOC variables.

Table 12: Principal Application Variables

Variable	Description
FRC.CarDirectionSwitch	Reverse (-1), Neutral (0), Forward (1)
FRC.FinalTorqueDesired*	Torque command after limits are imposed (same as ISR2TorqueDesired)
FRC.GearInterlock	Interlock based on pedal position and vehicle speed to enable transition between forward and reverse.
FRC.MaxAbsTorqueBySpeed*	Torque available based on speed (1= no derating, 0 = fully derated)
FRC.PedalS	Pedal Input reading (0-1), replaced ISR2PedalS
FRC.PedMode	Pedal zone indicator (acceleration, neutral, or braking)
FRC.PedTorqueDesired*	Torque request based on pedal position
FRC.PowerSaverSel	Selection of power-level
FRC.RegenState	Regenerative braking finite state machine indicator (formerly ISR2RegenState)
FRC.SpeedLimit	Torque limiting based on speed (0-1)
ISR2PedalS	Replaced by FRC.PedalS
ISR1PowerSaver*	Power saver potentiometer position, Azure internal use only
ISR2PowerSaverSel	Selection of power-level; replaced by FRC.PowerSaverSel
ISR2SpeedLimit	Torque limiting based on speed (0-1), replaced by FRC.SpeedLimit

CAN Status Reporting

While this application does not receive any command messages over CAN, it may be enabled to report status for use in vehicle displays. Setting the parameter EEXCANTxEnabled = 1 enables sending of all status messages.

Three status messages are available with the contents defined in Table 13. The CAN ID and transmit rate of each message may be individually configured, using the CAN parameters defined in Table 14. General CANbus settings are documented in the DMOC445 and DMOC645 User Manual.

Table 13: DMOC Status Messages Over CAN

	Message	Temperature Status Message						EEXCANTempStatusID
	Rate (sec)	1						EEXCANTempStatusCycleSec
	DLC	8						
	Format	standard						
	Direction	tx						
	Endian	big						
Byte	Signal Name	Min	Max	Res	Units	Width	Offset	Details
0	motor stator temperature	-40	200	1	C	8	-40	based on ISR2MotorLimit (see note below)
1	inverter temperature	-40	200	1	C	8	-40	ISR2HeatsinkTemp
2,3,4,5	reserved							
6	CAN interface level	0	240	1	n/a	8	0	FRC_CAN_REV
7	rolling counter	0	255	1	n/a	8	0	Value increments with each message to show DMOC is alive
	Message	Mechanical Status Message						EEXCANMechStatus1ID
	Rate (sec)	0.02						EEXCANMechStatus1CycleSec
	DLC	8						
	Format	standard						
	Direction	tx						
	Endian	big						
Byte	Signal Name	Min	Max	Res	Units	Width	Offset	Details
0,1	motor torque actual	-3000	3000	0.1	Nm	16	-3000	ISR2RealTorque
2,3	motor speed actual	-20000	20000	1	rpm	16	-20000	ISR2HertzWF
4	powerstage state	0	240	1	n/a	8	0	ISR2PowerStageState
5	active fault (enum)	0	240	1	n/a	8	0	ISR2PSFaultActive (see DMOC445 and DMOC645 User Manual)
6	status code	0	255	1	n/a	8	0	ISR2StatusCode (see DMOC445 and DMOC645 User Manual)
7	reserved							
	Message	Electrical Status Message						EEXCANElecStatus1ID
	Rate (sec)	0.02						EEXCANElecStatus1CycleSec
	DLC	8						
	Format	standard						
	Direction	tx						
	Endian	big						
Byte	Signal Name	Min	Max	Res	Units	Width	Offset	Details
0,1	DC battery voltage	0	1000	0.1	V	16	0	ISR2BatVoltageWF
2,3	DC current	-500	500	0.1	A	16	-500	ISR2EstBatCurrent
4	thermal limit cause	0	240	1	n/a	8	0	ISR2ThermCurrentLimitCause
5,6,7	reserved							

Note that the Motor Temperature Sensor is a PTC designed to protect the motor, not provide a actual temperature feedback. The "temperature" reported over CAN is only intended to indicate if a problem exists, therefore, only three discrete values are provided: 20C if the temperature is OK and the motor can operate normally, 120C if some thermal derating is taking place and 200C if the motor is over temperature and completely thermal limited.

Note that ISR2BatVoltageWF is the filtered battery voltage, and is approximately equal to ISR2BatVoltage.

Note, all these messages are Big Endian Format (Motorola, most significant byte first) and all signed values have offsets equal to their maximum negative value. To find the desired value in the units you expect, take the raw value over CAN, multiply by the resolution and add the offset.

Example of Parsing a Temperature Signal:

Looking at a temperature signal, for example the inverter temperature, with a range -40C to 200C with a resolution of 1C and offset of -40C, the following table has some example conversions:

Hex Value	Decimal Value	Temperature
0x00	0	-40C
0x3C	60	20C
0xF0	240	200C
0xF1-0xFF	241-255	Error, invalid data

Example of Parsing the Mechanical Status Message:

For example, on startup the Mechanical Status Message content might read as follows:

75 30 4e 20 01 00 23 ff
Bytes 0 and 1 (0x7530) indicate zero torque (0x7530 = 30000 and 30000*0.1 – 3000 = 0 Nm).
Bytes 2 and 3 (0x4e20) indicate zero speed (0x4e20 = 20000 and 20000*1 – 20000 = 0 RPM).
Byte 4 shows the PowerStageState at 1 (READY).
Byte 5 shows there are no active errors.
Byte 6 shows the Status Code of 0x23 (hex) which corresponds to 00100011 (binary), which, as shown in the DMOC445 and DMOC645 User Manual, indicates the contactor is closed, power stage is ready, more torque and power are available. Note that bit 5 (the thermal limit active signal) is not relevant in the READY state.

Table 14: Application Specific CAN Parameters

Variable	Description
EEXCANElecStatus1ID	Electrical Status Message CAN ID
EEXCANElectStatus1CycleSec	Transmit rate for Electrical Status Message in seconds
EEXCANMechStatus1ID	Mechanical Status Message CAN ID
EEXCANMechStatus1CycleSec	Transmit rate for Mechanical Status Message in seconds
EEXCANTempStatusID	Temperature Status Message CAN ID
EEXCANTempStatusCycleSec	Transmit rate for Temperature Status Message in seconds
EEXCANTxEnabled	Set to 1 to enable status reporting of all messages. If set to zero, only the mechanical status message will be transmitted at a low frequency to indicate the DMOC is alive.

All CANIds are displayed as decimal numbers in ccShell. Many CAN tools work more naturally in hex, so note, for example, the default Mechanical Status ID of 577 in decimal = 0x241 in hex.

Application Parameters

Table 15 summarizes the most frequently used application parameters. Please refer to the DMOC445 and DMOC645 User Manual for information about other important DMOC parameters.

Table 15: Frequently Used Pedal Control Application Parameters.

Variable	Description
EEXMinAccelPower	Acceleration power limit (Max Range setting on tri-power switch)
EEXNormAccelPower	Acceleration power limit (Normal setting on tri-power switch)
EEXMaxAccelPower	Acceleration power limit (Max Power setting on tri-power switch)
EEXMaxRegenPower	Regen power limit
EEXNoIgnSwitch	Can be used to force drive enable
EEXPedAccel	Acceleration begins above this pedal position
EEXPedBrake	Regen begins below this pedal position
EEXPedHyst	Pedal dead band
EEXPedMax	Full acceleration torque above this pedal position
EEXPedZero	Full regen torque below this pedal position
EEXRegenOnSpeed	Speed above which regen is enabled
EEXFullBrakeSpeed	Speed above which full regen is possible
EEXNoBrakeSpeed	Speed below which no regen is possible
EEXAccelMaxTorque	Maximum allowable acceleration torque
EEXBrakeMaxTorque	Maximum allowable brake torque
EEXBrakeTorqueSlew	Slew rate limit to brake torque
EEXInterlockSpeedHigh	Speed above which shifting is disabled (except for going to neutral)
EEXInterlockSpeedLow	Speed below which shifting is interlocked with zero accelerator pedal input
EEXBrakeLightOffTorque	Torque below which the brake lights are turned off
EEXBrakeLightOnTorque	Torque above which the brake lights are switched on
EEXFullAccelPosSpeed	Maximum forward speed allowing full acceleration torque
EEXFullAccelNegSpeed	Maximum reverse speed allowing full acceleration torque
EEXTorqueSlew	Slew rate limit to torque when accelerating
EEXUnloadTorqueSlew	Slew rate limit in unload zone

Electrical Interface

Besides the high voltage connections, which are documented in the DMOC445 and DMOC645 User Manual, a number of low voltage signals are used for the "Pedal Controlled" application module. The 12V auxiliary supply needs to be able to source 10A of current and must be protected by a 15A fuse. The auxiliary supply also acts as an enable signal for the internal power supply of the DMOC. In other words, a DMOC requires 12V to be present in order to operate.

Three connectors exist on the side of the DMOC:

- 14 pin AMPSeal: For the motor speed-sensor cable (dedicated connector)
- 8 pin AMPSeal: For RS-232 and CAN communications
- 35 pin AMPSeal: Application interface connector

It is recommended that an Azure Dynamics "DMOC Interface Kit" be used for the connections of the pedal and control switches; however, it is also possible to implement a customized interface harness and use custom controls.

Note that all GND connections are at a common potential. For noise immunity, they should not be tied to vehicle ground (i.e. external to the DMOC). The exception to this is pin 13 on the DMOC 35-pin connector, which should be connected to 12V chassis ground.

Both the backup light and brake light signals are isolated from the DMOC GND and vehicle ground. They should be used in conjunction with a voltage source that is referenced to vehicle ground (for example the vehicle 12V battery). The signals are capable of sinking / sourcing 5A and should be fused externally with a 5A fuse. If more current is needed, then external relays with built-in free-wheeling diodes should be used. Such relays can be purchased from Panasonic or Bosch.

The power saver internal circuitry is pulled up to 3.3V through a 4.99kΩ resistor. The internal circuitry for forward and for reverse is pulled up to 3.3V through a 10kΩ resistor.

Please see Figure 11 for the Azure Dynamics DMOC Foundation Harness (part of the Azure Dynamics DMOC Interface Kit; mates to 35 pin connector) wiring diagram. Figure 12 shows a suggested customer interface.

Please note, some existing versions of the DMOC Foundation Harness may not have pins 30 and pins 23 and 12 populated on the mating DMOC 35-pin connector. Also, existing versions of the Foundation Harness do not include the back-up light relay. If you need assistance, please ask your Azure Dynamics or distributor contact.

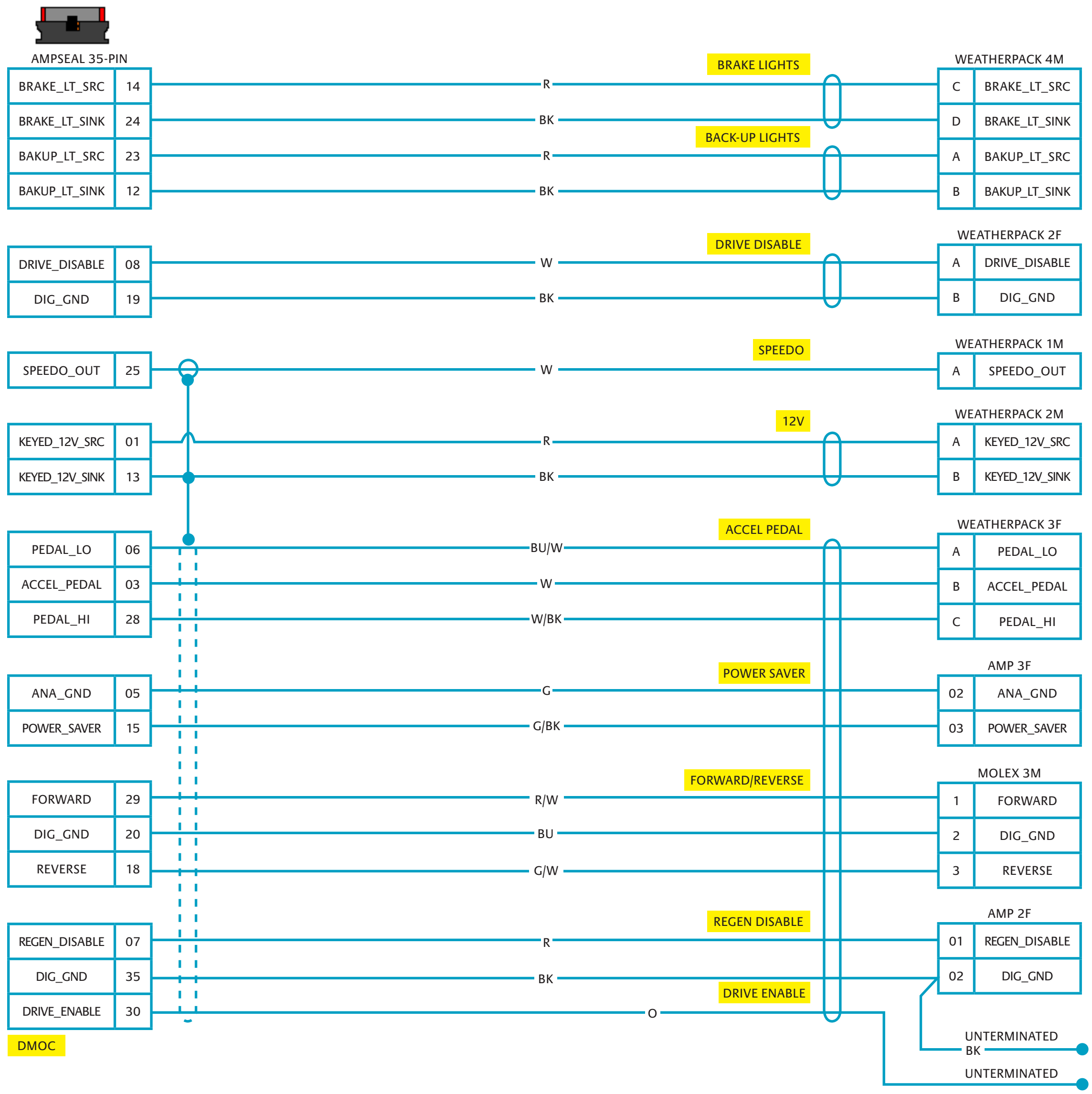
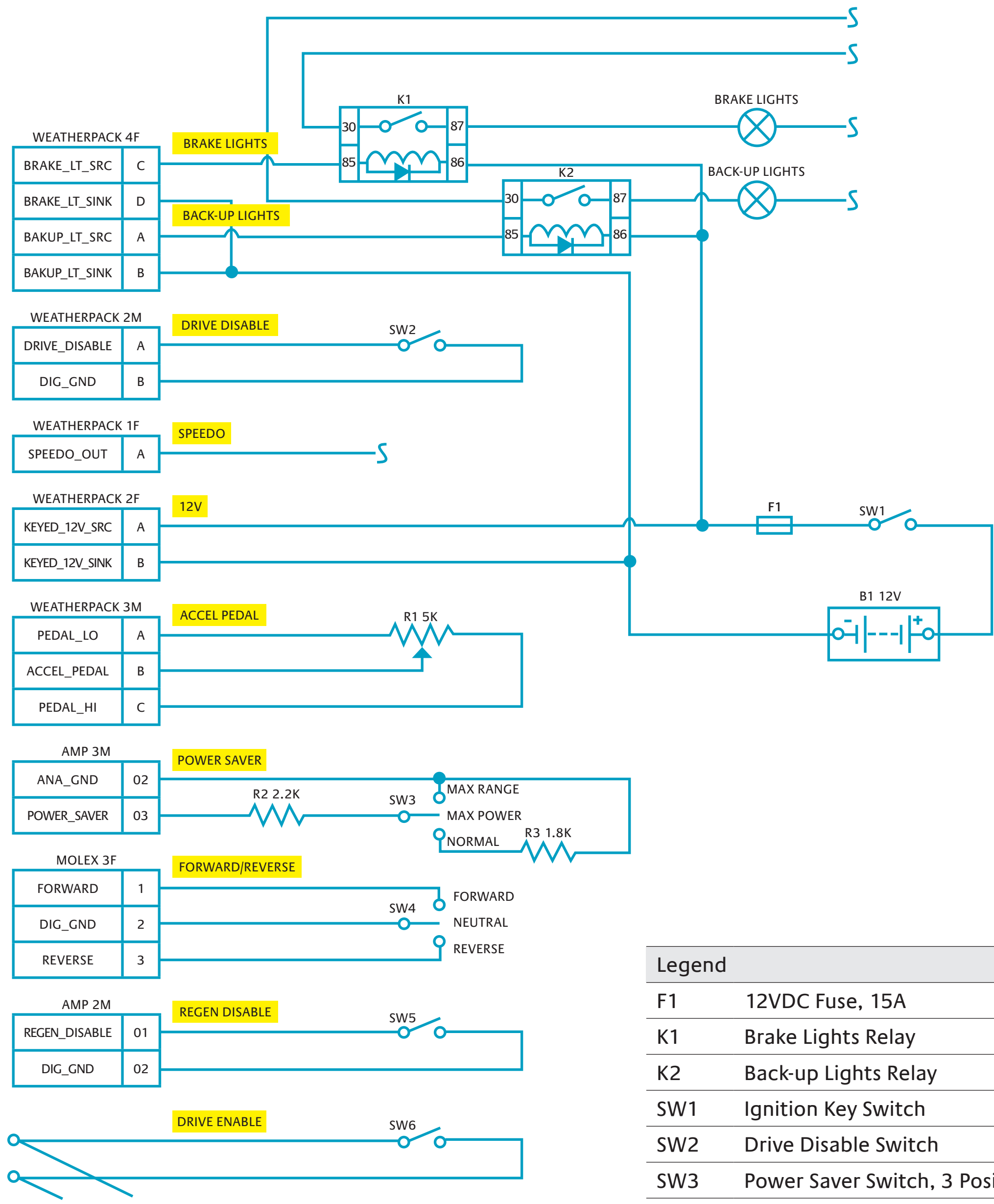


Figure 11: DMOC I/O Interface Harness (Foundation Harness)

NOTE: Vehicle brake and reverse lights wiring will vary. Diagram is provided for reference only.



NOTE: Splice directly to the wires or add a connector of your choice.

Legend	
F1	12VDC Fuse, 15A
K1	Brake Lights Relay
K2	Back-up Lights Relay
SW1	Ignition Key Switch
SW2	Drive Disable Switch
SW3	Power Saver Switch, 3 Position
SW4	Forward/Reverse Switch, 3 Position
SW5	Regen Disable Switch
SW6	Drive Enable Switch
R1	Accelerator Pedal Potentiometer, 5K
R2	Resistor, 2.2K
R3	Resistor, 1.8K
B1	12VDC Battery

Figure 12: Suggested DMOC Customer Interface I/O

DMOC Interface Kit

The Azure Dynamics DMOC Interface Kit consists of the following items:

- Accelerator / Brake Controller (ABC)
- Tri-Power Switch
- Foundation Harness
- Tail Lamp Harness (note, older versions include only the Regen Brake Harness)

Note, the accelerator pedal is NOT included. Any pedal that works with a 5kΩ pot is acceptable.

Accelerator Brake Controller

The DMOC is designed for a 5kΩ linear pedal pot, which is part of the Accelerator Brake Controller in the Azure Dynamics DMOC Interface Kit, please see Figure 13. A pot with a different range can be used, but it needs to be calibrated using the pedal map; please see Figure 3 and Figure 4.

The 5kΩ linear pot is a variable resistor being used as a voltage divider. All pots, including this one, have three wires, but sometimes all three aren't used. In the Azure Dynamics pot, Pin 3 is the wiper, Pin 28 is Pedal High, and Pin 6 is Pedal Low. Azure specifies a 5kΩ pot and does not recommend the use of pedals which have a voltage output.

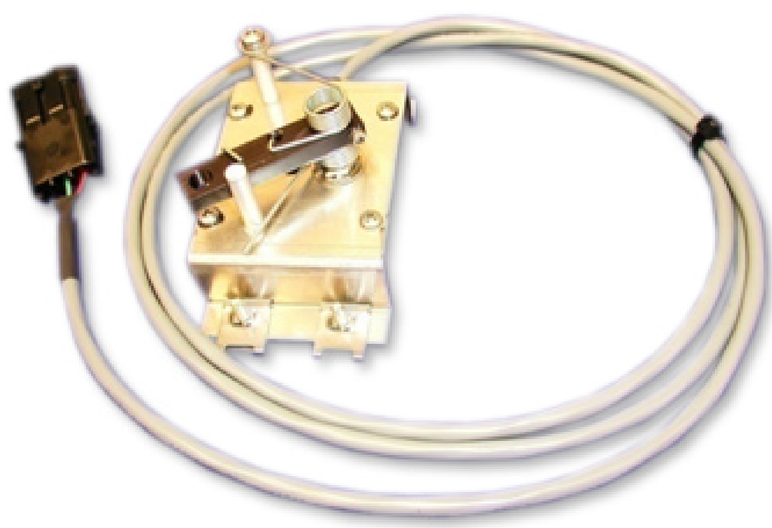


Figure 13: Accelerator Brake Controller (ABC-1)

Tri-Power Switch

The Tri-Power Switch implements several functions:

- Fwd/Rev Switch
- Battery Power Selection (Max Power, Normal, Max Range)
- Disable switch for electric braking (regen)
- Reverse light control
- Back-up light control
- Cabin heater control

Please see Figure 14. Note that the three wires to the heat switch, the one reverse lamp connector, regen disable and the one neutral interlock connector are not needed for DMOC operation.

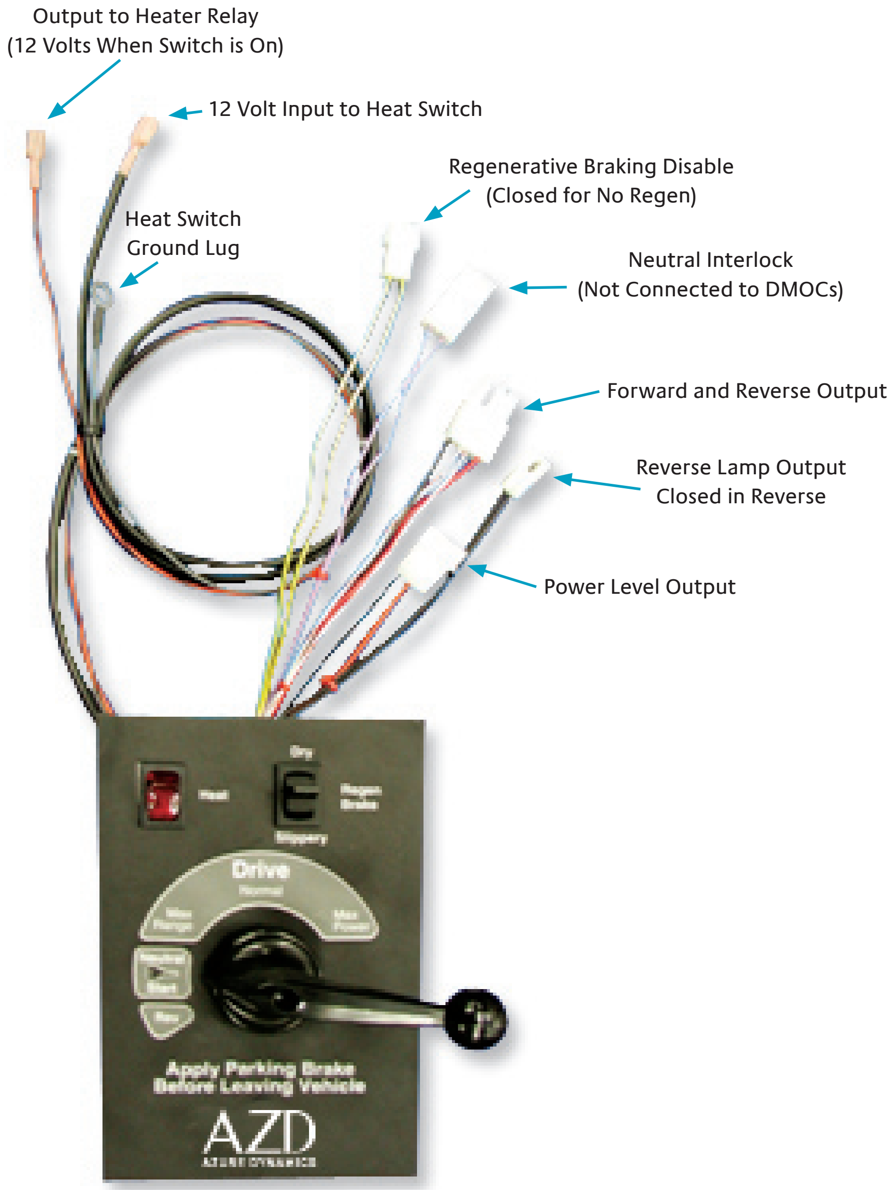


Figure 14: Tri-Power Switch

Foundation Harness

The Foundation Harness provides the wiring between the connections between the DMOC and the other Interface Kit Components. See Figure 15 and Figure 16. The wiring diagram for the Foundation Harness is shown in Figure 11 and Figure 12.

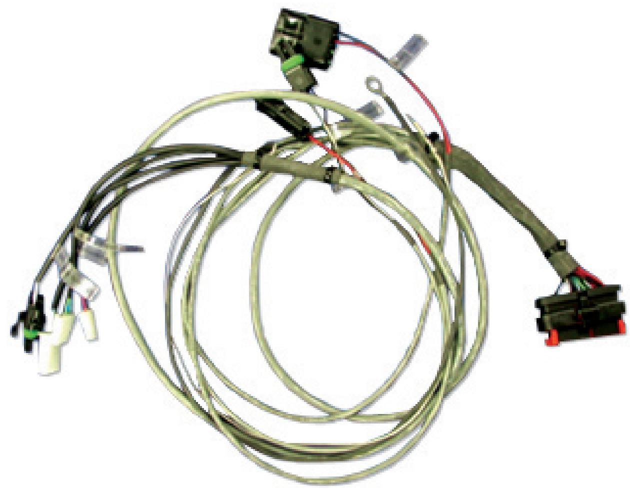


Figure 15: Foundation Harness

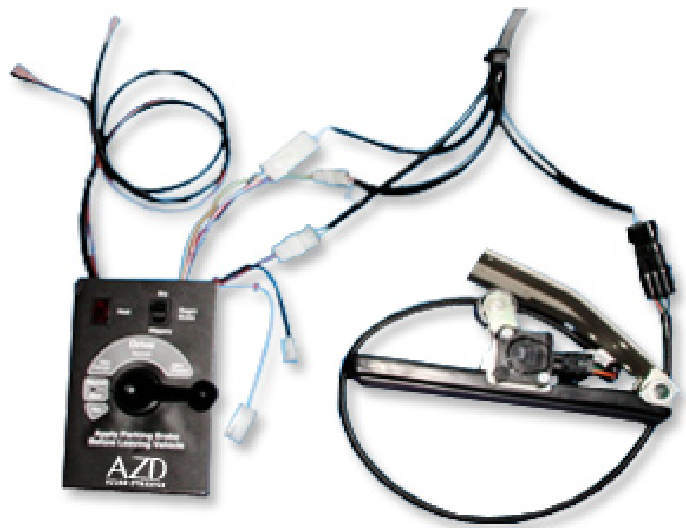


Figure 16: Tri-Power Switch and Pedal Connections

Besides the connections to the Tri-Power Switch and the accelerator pedal (note, pedal is not included in Interface Kit) shown in Figure 16, the following connections are made:

— Keyed 12 volt: Black is ground, Red is + 12 volts
— Speedometer Output: Optional. See Troubleshooting and More Details.
— Charger Interlock: Optional. This keeps the vehicle from being driven while the charger is connected. Closing (connecting the white wire to the black wire) this interlock will keep the DMOC from driving the motor.

Table 16 summarizes the wiring of the Azure Dynamics Foundation Harness; see also the 35-Pin Connector Pinout information in the DMOC445 and DMOC645 User Manual.

Table 16: Azure Dynamics Foundation Harness Wiring

Signal	Source Connector	Pin	Cable Recommendation	Color/ Stripe	Destination Connector	Pin
REGEN_DISABLE	AMP35	7	22AWG 15 cond grey shielded	red	AMP2F Plug	1
GND_D	AMP35	35	22AWG 15 cond grey shielded	black	AMP2F Plug	2
POWER_SAVER	AMP35	15	22AWG 15 cond grey shielded	green / black	AMP3F Plug	3
GND_A	AMP35	5	22AWG 15 cond grey shielded	green	AMP3F Plug	2
FORWARD-	AMP35	29	22AWG 15 cond grey shielded	red / white	Molex 3M Intl Plug	1
REVERSE-	AMP35	18	22AWG 15 cond grey shielded	green / white	Molex 3M Intl Plug	3
GND_D	AMP35	20	22AWG 15 cond grey shielded	blue	Molex 3M Intl Plug	2
SPEEDO_BUF	AMP35	25	22AWG 15 cond grey shielded	white	Weatherpack 1M	A
KEYED_12V_SRC	AMP35	1	18AWG 2 cond grey	red	Weatherpack 2M	A
KEYED_12V_SINK	AMP35	13	18AWG 2 cond grey	black	Weatherpack 2M	B
PEDAL_LO	AMP35	6	22AWG 15 cond grey shielded	blue / white	Weatherpack 3F	A
ACCEL_PEDAL	AMP35	3	22AWG 15 cond grey shielded	white	Weatherpack 3F	B
PEDAL_HI	AMP35	28	22AWG 15 cond grey shielded	white / black	Weatherpack 3F	C
DRIVE_DISABLE-	AMP35	8	20AWG 2 cond grey shielded	white	Weatherpack 2F	A
GND_D	AMP35	19	20AWG 2 cond grey shielded	black	Weatherpack 2F	B
BRAKE_LT_SRC	AMP35	14	18AWG 2 cond grey	red	Weatherpack 4M	C
BRAKE_LT_SINK	AMP35	24	18AWG 2 cond grey	black	Weatherpack 4M	D
BACKUP_LT_SRC	AMP35	23	18AWG 2 cond grey	red	Weatherpack 4M	A
BACKUP_LT_SINK	AMP35	12	18AWG 2 cond grey	black	Weatherpack 4M	B

Important: None of the GND_D and GND_A pins should be connected to vehicle chassis (i.e. external to the DMOC).

Tail Lamp Harness

The Tail Lamp Harness is illustrated in Figure 17.

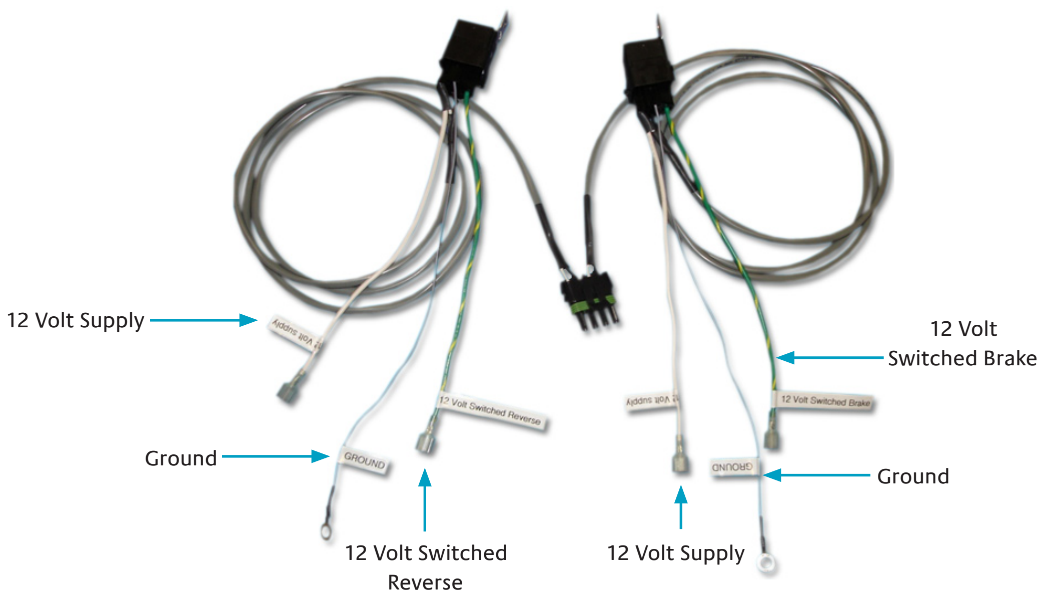


Figure 17: Tail Lamp Harness

Troubleshooting and More Details

Minimum Connections for Operation

The DMOC requires (in order)

1. high voltage connected inside the junction box
2. 12 volts on pin 1 on 35-pin connector
3. ground pin 13 on 35-pin connector to the 12V return
4. connect pins 19 and 29 on 35-pin connector to each other

The DMOC should power up and spin the motor once the pedal is pressed.

However, pins 19 and 29 cannot be left connected (Step 4 provides a "forward" request.) This is because the DMOC contactor needs to close and then the DMOC needs to see a neutral signal and then a forward signal each time the DMOC is power-cycled.

Please refer also to the "Safety and Interlocks" section of this manual.

Speedometer/Tachometer

The DMOC has a frequency-modulated 12V push-pull output (open-emitter gauge drive) that can drive some speedos/tachs. Azure has had success with the Continental (was Siemens) VDO, "Cockpit Series", 85mm diameter, wired to work with "electronic transmissions". This output is Pin 25 from the DMOC 35-pin connector, marked on the Azure Foundation Harness in the Azure DMOC Interface Kit.

Speedometer Installation and Operation Instructions (Download PDF)

http://usa.vdo.com/generator/www/us/en/vdo/main/products_solutions/cars/performance_instruments/vdo_performance_instruments/instrument_series/cockpit/speedometers/download/flc_0515012051programmablespeedometer_en.pdf

The DMOC parameter called EE1SpeedoDiv can be adjusted for specific speedos/tachs. However, every speedo/tach is different and the software isn't designed to work with all of them.

To calibrate EE1SpeedoDiv:

- Connect speedo output to speedometer
- Calculate km/h corresponding to 2500 rpm at the motor
- Don't spin the motor during the calibration process
- Set EE1SpeedoDiv = -100, speedometer should move
- If reading is higher then km/h calculate above, make the number more negative (e.g. -110)
- If reading is lower then km/h calculate above, make the number less negative (e.g. -90)
- Once the speedometer displays the correct speed, flip the sign of EE1SpeedoDiv (make it a positive number)
- Now drive the vehicle and double-check speedometer calibration

The equation for the speedo is $2 \times rpm \div EE1SpeedoDiv \approx speedo\ output\ frequency.$

Regenerative Braking on Brake Pedal Instead of Accelerator Pedal

Azure Dynamics' system normally has regenerative braking on the accelerator pedal. Some customers have expressed interest in moving regen to the brake pedal. The regen brake light switch can be tied into the Regen Disable signal (using a relay) so that regen comes on only when the accelerator pedal has been released and the brake pedal has been pressed. This is the reverse of having the controller turn on the brake lights when you release the accelerator.

This change actually reverses the function of the regen relay. In the Azure Dynamics DMOC Interface Kit, the regen brake light relay turns on the brake lights when the DMOC is in regen mode. With this modification, the regen relay is eliminated and replaced with a similar (but normally closed) relay to activate the regen function when the brake lights come on.

A normally closed relay would need to be installed so that when the brake lights come on, the relay opens up and lets the regen circuit activate on the DMOC.

Fault Clearing

Most DMOC faults are cleared by releasing the accelerator pedal completely and cycling through neutral. See also the sections discussing faults on the DMOC445 and DMOC645 User Manual.

DMOC Variable Capture with ccShell for Troubleshooting

If you cannot communicate with your DMOC using ccShell, see the ccShell User Manual and the DMOC445 and DMOC645 User Manual.

If you are having problems getting your system running, or if the performance is less than expected, Azure Dynamics or your distributor will typically ask you to capture some data from the DMOC using your laptop computer and Azure's ccShell Java-based shell program. You should have received information on how to access and use both this program and the .ccs viewer file when your DMOC was shipped to you. Please see the ccShell User Manual for more details.

If your motor will not spin:

Do you hear the contactor (relay) close inside the DMOC? See the "Troubleshooting" section of the main DMOC manual, the DMOC445 and DMOC645 User Manual. See also "Minimum Connections Required for Operation" above.

Please save the .par file (DMOC parameter file) from your DMOC and email it to your your Azure Dynamics or distributor contact.

Please also capture 10-20 seconds worth of ccShell data and email the resulting .txt file it to your Azure Dynamics or distributor contact. Set the ccShell capture interval to one (1) second. Make sure you press the accelerator pedal or engage the throttle pot completely and release it completely during the test. The list of variables to capture varies depends on which software revision you have, but if you start with the default list, that may be sufficient to determine the problem. Alternatively, here is one possible list of 20 variables:

1. FRC.CarDirectionSwitch
2. FRC.PedalS
3. ISR2BatVoltage
4. ISR2ContactorState
5. ISR2DriveEnabled
6. ISR2EstBatCurrent
7. ISR2HeatsinkTemp
8. ISR2Hertz
9. ISR2IdSet
10. ISR2IqSet
11. ISR2IsLimit
12. ISR2MotorPTCVoltage
13. ISR2MotorTorqueLimitCause
14. ISR2PowerStageState
15. ISR2PSFaultActive
16. ISR2RealTorque
17. ISR2TorqueDesired
18. ISR2VdF
19. ISR2VqF
20. ISR2VsF

If your system is operating but you expected better performance:

Make sure that both your accelerator pedal and the pedal potentiometer have the full range of mechanical travel. Make sure you are in “Max Power” mode; see “Power Saver Selector” section above. Check that your battery pack is in good shape and is fully charged to at least the nominal voltage that your DMOC was programmed for. Check that there are no mechanical issues with your vehicle such as a slipping clutch, dragging brake pad, etc.

Please save the .par file (DMOC parameter file) from your DMOC and email it to your Azure Dynamics or distributor contact.

Using ccShell, please also capture at least 30-60 seconds worth of data and email the resulting .txt file it to your Azure Dynamics or distributor contact.

Set the ccShell capture interval to one (1) second. Start the capture, press the accelerator to the floor or until the vehicle reaches its top speed, release the pedal and stop the capture.

The variables to capture will depend on your software revision, but the following list of 20 variables is an example:

1. FRC.PedalS
2. ISR2BatVoltage
3. ISR2EstBatCurrent
4. ISR2HeatSinkLimit
5. ISR2Hertz
6. ISR2IdF
7. ISR2IdSet
8. ISR2IqF
9. ISR2IqSet
10. ISR2IsF
11. ISR2IsLimit
12. ISR2MaxPowerOut
13. ISR2MotorLimit
14. ISR2MotorTorqueLimitCause
15. ISR2PSFaultActive
16. ISR2RealTorque
17. ISR2TorqueDesired
18. ISR2VdF
19. ISR2VqF
20. ISR2VsF

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