



AZURE
D Y N A M I C S

Pedal Controlled DMOC Manual & Operating Instructions

Azure Dynamics Inc.

9 Forbes Road

Woburn MA 01801 USA

781-932- 9009

Fax 781-932-9219

customerservice@azuredynamics.com

www.azuredynamics.com

Approvals:

Project Engineer _____ Date: _____

Customer Service _____ Date: _____

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1. Foreword

1. 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 Warrantee!

2. 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 Customer Service Department at the phone number provided. Please be prepared to provide the following information:

Your name

Name and edition of your manual

Page number(s) where the error(s) appear

Serial number of your unit

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 8AM to 5:30PM USA Eastern Time:

Phone 781-932-9009

Or Fax 781-932-9219 or email customerservice@azuredynamics.com

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2. 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 Customer Service Department before proceeding.

1. Warning Labels

Labels will be located on the right-hand side of the page to indicate areas in a procedure where you should take appropriate precautions. Labels include:



WARNING and DANGER



**RISK OF
ELECTRIC
SHOCK**

2. 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 the right-hand margin of 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 the Azure Dynamics Customer Service Department.



3. Overview

The Azure Dynamics Digital Motor Controller (DMOC) 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

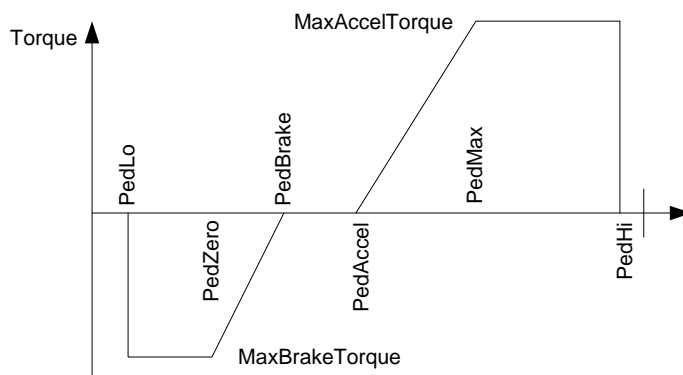
For general information regarding the DMOC, including important safety instructions and warnings, the “DMOC445 Manual & Operating Instructions” should be consulted which is distributed and revised separately.

Azure’s PC-based diagnostics/calibration tool ccShell allows the user to access and modify DMOC calibrations and to visualize and capture signals in real time. 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 manual for information on how to install and use this tool.

4. Application Software

1. Pedal Map

The pedal maps the accelerator pedal position into a desired torque. The map itself is completely configurable by parameters. Three valid zones can be distinguished (see Figure 1 -- for better readability, the EEX parameter prefixes of the parameter names are omitted):



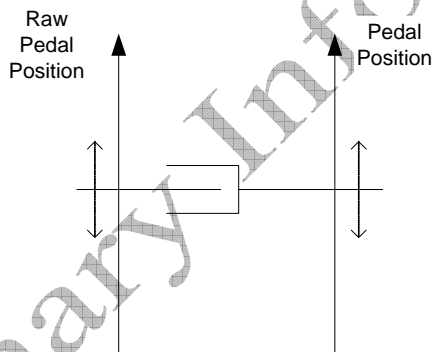
- **Brake Zone:** The first zone of the pedal is used to control regenerative braking. It ranges from PedLo (fixed) to EEXPedBrake. Full torque (EEXMaxBrakeTorque) is applied when the accelerator pedal is not depressed at all. As the pedal is depressed past EEXPedZero, the brake torque is ramped down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

FSM Variable:		ISR2PedMode
State	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

Any pedal values below PedLo or above PedHi are consider to be a pedal fault (short or open) and will result in no torque.

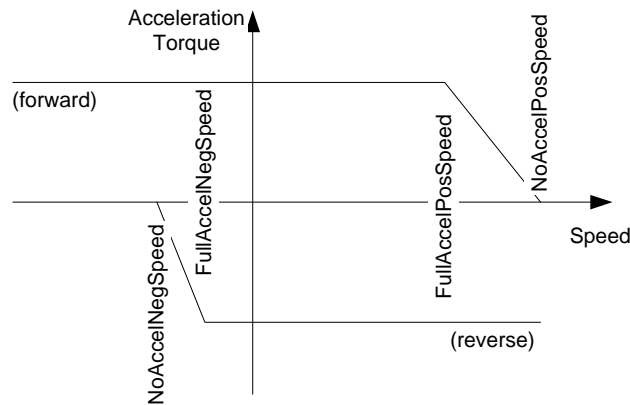
In some vehicles, a strong feedback between the vehicle's motion and the driver's foot exists. It can lead to unwanted oscillations and may cause serious drivability problems. An effective method to break the resonance is to add a dead band to the position sensing; this is illustrated in the figure below. 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 ISR2PedalS.

Parameter	Description
EEXMaxAccelTorque	Maximum acceleration torque when pedal is fully depressed
EEXMaxBrakeTorque	Maximum braking torque when pedal is not depressed at all
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)



2. Speed Ramps

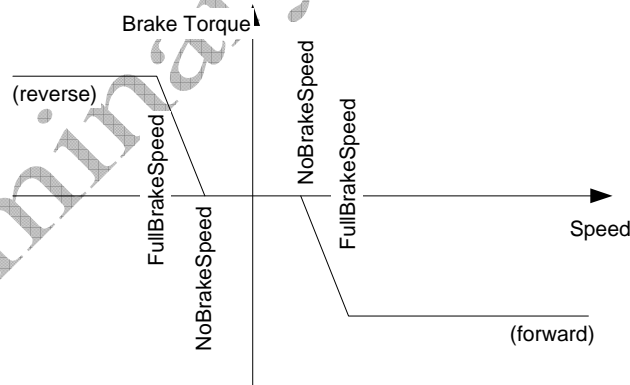
Several ramps are required to reduce and limit the drive torque in managing vehicle speed. The purpose of these ramps is to prevent the vehicle from over speeding, both in reverse (for safety) and in forward (for motor protection). Furthermore, during regenerative braking, it is necessary to reduce the brake torque to zero before the vehicle starts reversing its direction. This is illustrated in the figure below. Similar to the pedal map, the speed ramps are fully configurable by means of parameters.



Speed Ramps under Acceleration

Parameter	Description
EEXFullAccelPosSpeed	Positive motor speed up to which full acceleration torque (EEXMaxAccelTorque) is allowed
EE2NoAccelPosSpeed	Positive motor speed above which acceleration torque is zero
EEXFullAccelNegSpeed	Negative motor speed up to which full acceleration torque (EEXMaxAccelTorque) is allowed
EE2NoAccelNegSpeed	Negative motor speed above which acceleration torque is zero

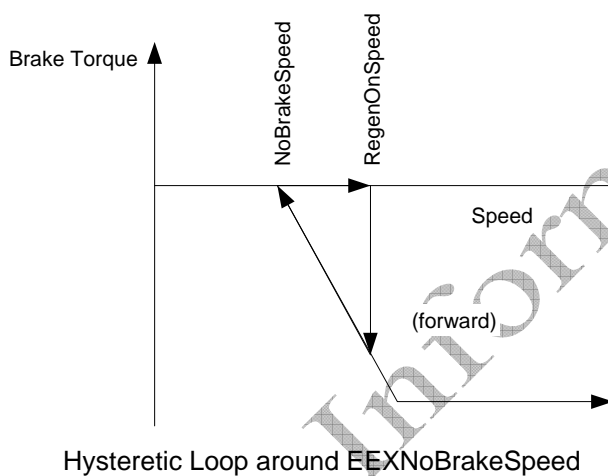
* Note: Torque is linearly ramped between EEXFullAccelPosSpeed and EE2NoAccelPosSpeed, and between EEXFullAccelNegSpeed and EE2NoAccelNegSpeed



Speed Ramps When Braking

In order to avoid oscillations around the EEXNoBrakeSpeed point, a hysteretic loop is implemented as shown in the following figure. 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 is implemented by the Regen FSM (see below) and has proven to be successful in avoiding brake torque oscillations at very low speeds.

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

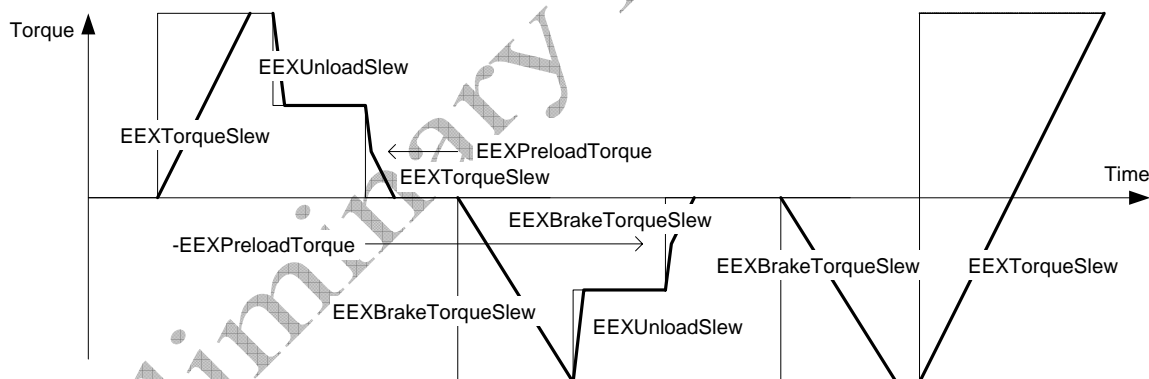


FSM Variable: ISR2RegenState		
State	Name	Description
0	POWERUP	Regenerative braking feature not initialized properly
1	REGEN_STATE_DISABLED	Regenerative braking feature is disabled
2	REGEN_STATE_ENABLED	Regenerative braking feature is enabled
3	REGEN_STATE_FAULT	Regenerative braking feature has a problem

3. 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 Force Extension Module provides several parameters to tune the slew rates (see Figure 7). Depending whether positive torque (acceleration) or negative torque (braking) is desired, the following limits apply:

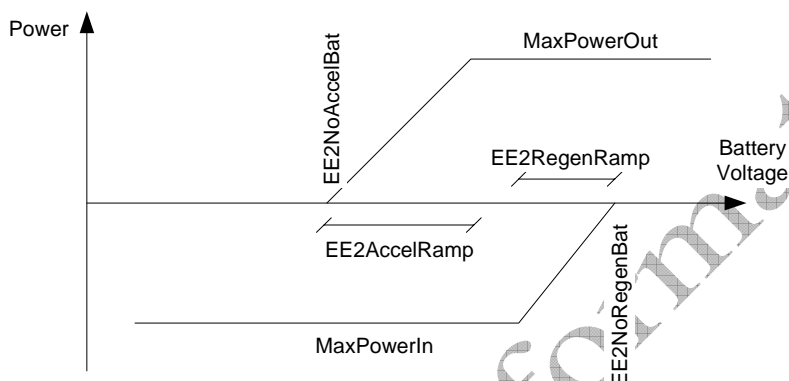
Acceleration Torque	Torque < 0	EEXPreloadTorque > Torque > 0	Torque > EEXPreloadTorque
Increase	EEXTorqueSlew		
Decrease	N/A	EEXTorqueSlew	EEXUnloadSlew
Brake Torque	Torque > 0	-EEXPreloadTorque < Torque < 0	Torque < -EEXPreloadTorque
Increase	EEXBrakeTorqueSlew		
Decrease	N/A	EEXBrakeTorqueSlew	EEXUnloadSlew



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
EEXPreloadSlew	Slew rate close to zero torque

4. Battery Protection

The DC source (typically a battery) is protected from overcharge or over discharge by means of ramps, as shown in the figure below.



Warning: While the battery ramps are effective in protecting lead-acid batteries, this protection is not adequate for batteries which do not tolerate under-voltage or over-voltage events, such as it is the case with lithium chemistry-based batteries.

While the battery power limit for regenerative braking (power flows into the battery) is fixed, the acceleration power level is selectable using a three-position selection switch (part of the DMOC Interface Kit).

Parameter	Description
EE2NoAccelBat	Battery voltage below which acceleration is zero
EE2AccelBatRamp	Voltage range above EE2NoAccelBat where maximum allowed acceleration power is linearly ramped to EEXMaxAccelPower or EEXNormAccelPower or EEXMinAccelPower
EE2NoRegenBat	Battery voltage above which no regen is allowed
EE2RegenBatRamp	Voltage range below EE2NoRegenBat where maximum allowed regen power is ramped from EEXMaxRegenPower to zero

The battery power limit for acceleration is selectable by means of the “Tri-Power Switch” (part of the “DMOC Interface Kit”) which connected to the “Power Saver” input. While the “Power Saver” is an analog input, it is mapped into three zones:

1. Max Power: Power limit set to EEXMaxAccelPower
2. Normal Power: Power limit set to EEXNormAccelPower
3. Maximal Range: Power limit set to EEXMinAccelPower

FSM Variable: ISRPowerSaverSel		
State	Name	Description
0	POWERUP	Power Saver not initialized correctly
1	MAX_POWER_SELECT	EEXMaxAccelPower is the selected power limit
2	NORM_POWER_SELECT	EEXNomAccelPower is the selected power limit
3	MIN_POWER_SELECT	EEXMinAccelPower is the selected power limit

5. Interlocks & Safety

At power up, the DMOC will remain interlocked (and disabled) as long as either the accelerator pedal is depressed or the gear switch is in forward or reverse.

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. If the drive enable feature is not desired, it can be switched off by setting the calibration EEXNolgnSwitch to 1. Grounding *drive disable* will always result in disabling the DMOC.

Parameter	Description
EEXNolgnSwitch	1 = Drive Enable input ignored

For an emergency shutoff, it is recommended that the auxiliary 12V/24V be disconnected rather than using the ignition signal to disable the DMOC. Removing the auxiliary power will immediately disable the DMOC power supply and shut the unit down. For additional safety, it is recommended that a high voltage disconnect be provided as well.

Non-critical DMOC faults are automatically cleared by releasing the accelerator pedal and cycling the gear switch through the neutral position.

6. Principal Application Variables

The following is a table of the most frequently viewed application variables. The reader is referred to the "DMOC445 Manual & Operating Instructions" for information about other important DMOC variables.

Variable	Description
ISR2PedalS	Pedal Input reading
ISR2PedTorqueDesired	Torque request based on pedal position
ISR2FinalTorqueDesired	Torque command after limits are imposed
ISR2RegenState	Regenerative braking finite state machine indicator

ISR2PedMode	Pedal zone indicator (acceleration, neutral, or braking)
ISR2CarDirectionSwitch	Reverse (-1), Neutral (0), Forward (1)
ISR2PowerSaverSel	Selection of power-level
ISR1PowerSaver	Power saver potentiometer position
ISR2DriveEnabled	Equals to 1 if drive is enabled
ISR2MaxAbsTorqueBySpeed	Torque available based on speed (1= no derating, 0 = fully derated)
ISR2MaxAbsPower	Maximal power allowed for acceleration

7. Application Parameters

The table below summarizes the most frequently used application parameters. The reader is referred to the “DMOC445 Manual & Operating Instructions” for information about other important DMOC parameters.

Variable	Description
EEXTorqueSlew	Slew-rate limit to torque
EEXMinAccelPower	Acceleration power limit (max range)
EEXNormAccelPower	Acceleration power limit (normal)
EEXMaxAccelPower	Acceleration power limit (max power)
EEXMaxRegenPower	Regen power limit
EEXNoIgnitionSwitch	Can be used to force drive enable
EEXPedZero	Full Regen Pedal Position
EEXPedBrake	Zero Regen Pedal Position
EEXPedAccel	Zero Accel Pedal Position
EEXPedMax	Full Accel Pedal Position
EEXPedHyst	Pedal Dead band
EEXRegenOnSpeed	Speed above which regen is enabled
EEXNoBrakeSpeed	Speed below which no regen is possible
EEXFullBrakeSpeed	Speed above which full regen is possible
EEXAccelMaxTorque	Maximal allowable Acceleration Torque
EEXBrakeTorqueSlew	Slew rate limit to brake torque
EEXBrakeMaxTorque	Maximal allowable brake torque
EEXInterlockSpeedLow	Speed below which shifting is interlocked

EEXInterlockSpeedHigh	Speed above which shifting is disabled (except for going to neutral)
EEXBrakeLightOnTorque	Torque above which the brake lights are switched on
EEXBrakeLightOffTorque	Torque below which the brake lights are turned off
EEXFullAccelPosSpeed	Maximal forward speed allowing full acceleration torque
EEXFullAccelNegSpeed	Maximal reverse speed allowing full acceleration torque
EEXTorqueSlew	Slew rate limit to torque when accelerating
EEXBrakeTorqueSlew	Slew rate limit to torque when accelerating
EEXPreloadTorqueSlew	Slew rate limit in preload zone
EEXUnloadTorqueSlew	Slew rate limit in unload zone

5. Electrical Interface

Besides the high voltage connections, which are documented in the “DMOC445 Manual & Operating Instructions”, a number of low voltage signals are used for the “Pedal Controlled” application module. 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

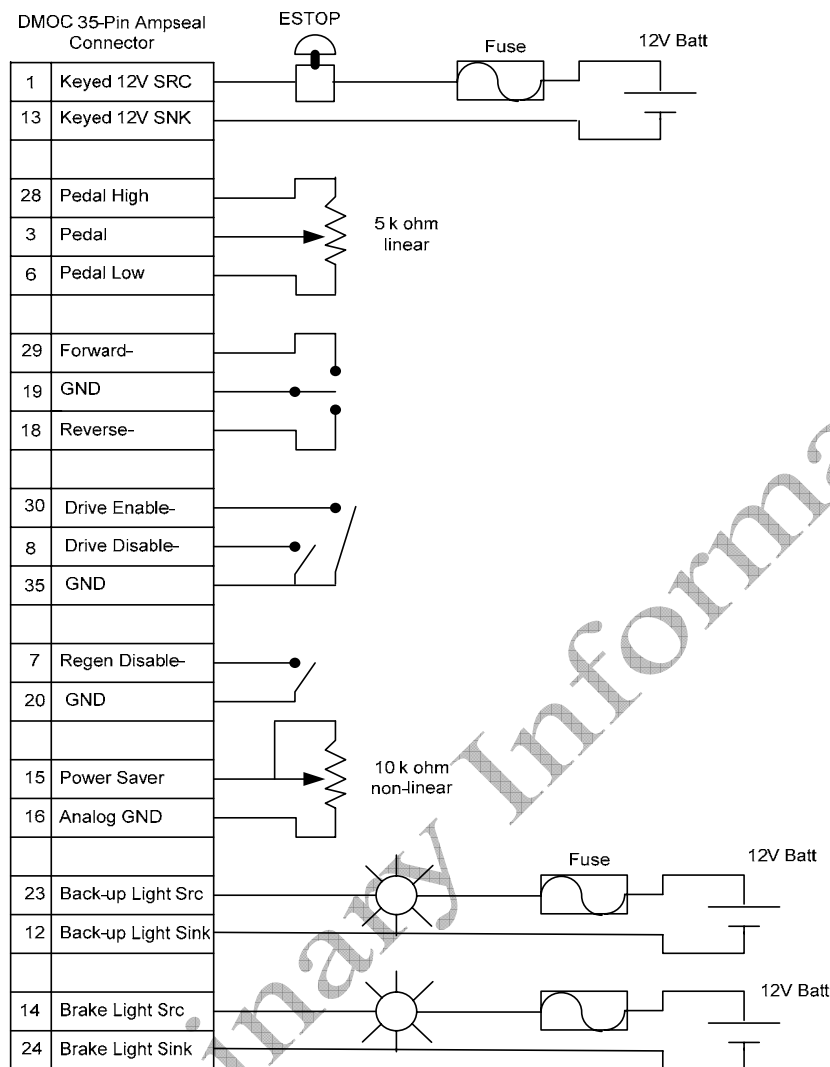
It is recommended that a “DMOC Interface Kit” be used for the connections the pedal and control switches; however, it is also possible to implement a customized interface harness and use custom controls.

Note that all GND connections are at a common potential. For noise immunity, they should *not* be tied to vehicle ground.

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 5 A and should be fused externally. 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 resistance across the power saver input (pins 15 & 16) determines the power saver setting as follows:

- Maximal Range: $R < 3.8 \text{ k}\Omega$
- Normal: $3.8 \text{ k}\Omega < R < 8.15 \text{ k}\Omega$
- Maximal Power: $R > 8.15 \text{ k}\Omega$

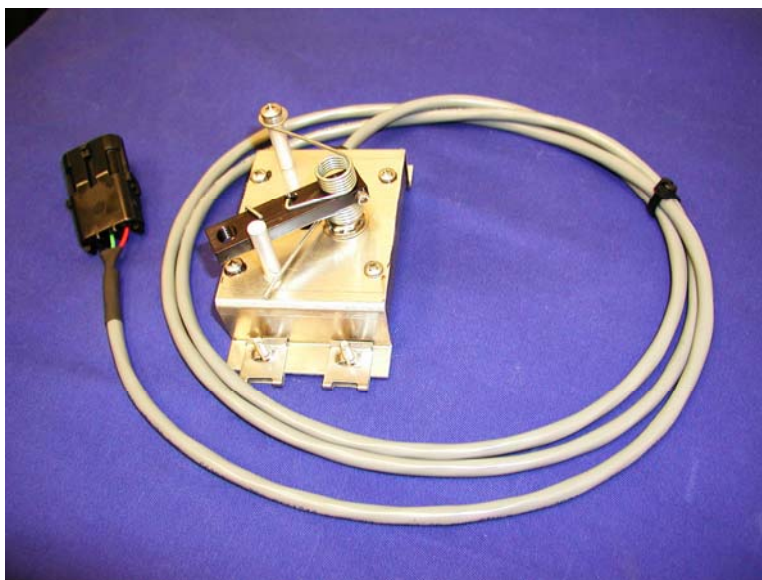


1. DMOC Interface Kit

The DMOC Interface Kit consists of the following items:

- Accelerator / Brake Controller (ABC)
- Tri-Power Switch
- Foundation Harness
- Regen Brake Harness

2. Accelerator Brake Controller



3. Tri Power Switch

The Tri-Power Switch implements several functions:

- Fwd/Rev Switch
- Battery Power Selection
- Disable switch for electric braking (regen)
- Reverse light control
- Cabin heater control

Note that the three wires to the heat switch, the one reverse lamp connector, and the one neutral interlock connector are not needed for DMOC operation.



4. Foundation Harness

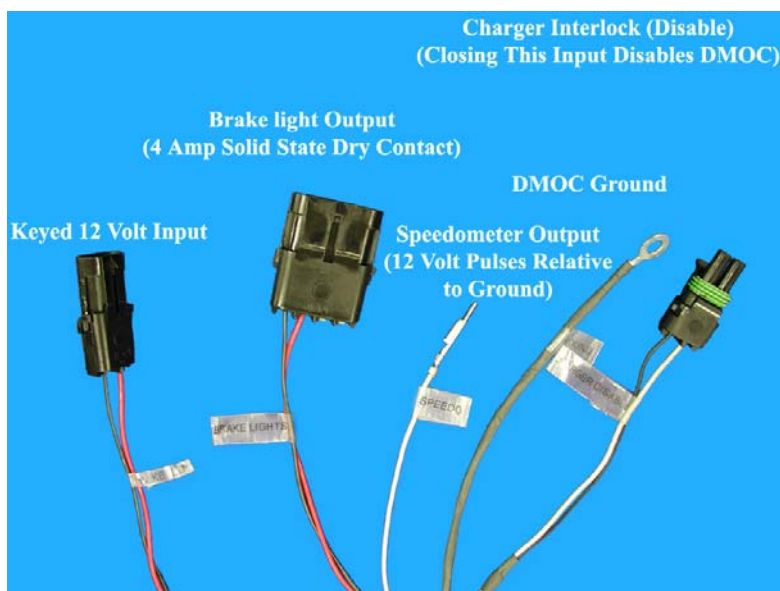
The Foundation harness provides the wiring between the connections between the DMOC and the other Interface Kit Components.





Besides the connections to the Tri-Power Switch and the Accelerator Pedal shown in the figure above, the following connections must be made:

- Keyed 12 volt: Black is ground, Red is +12 volts
- Brake Light Output: 4 Amp Solid State Dry Contact Black connected to ground, Red connected to ground side of a load (think of this output as a switch in series with the load)
- Speedometer Output: Is not supported with most software.
- DMOC Ground: Connect this to the vehicle ground.
- Charger Interlock: This keeps the vehicle from being driven while the vehicle is being charged. Closing (connecting the white wire to the black wire) this will keep the DMOC from driving the motor.



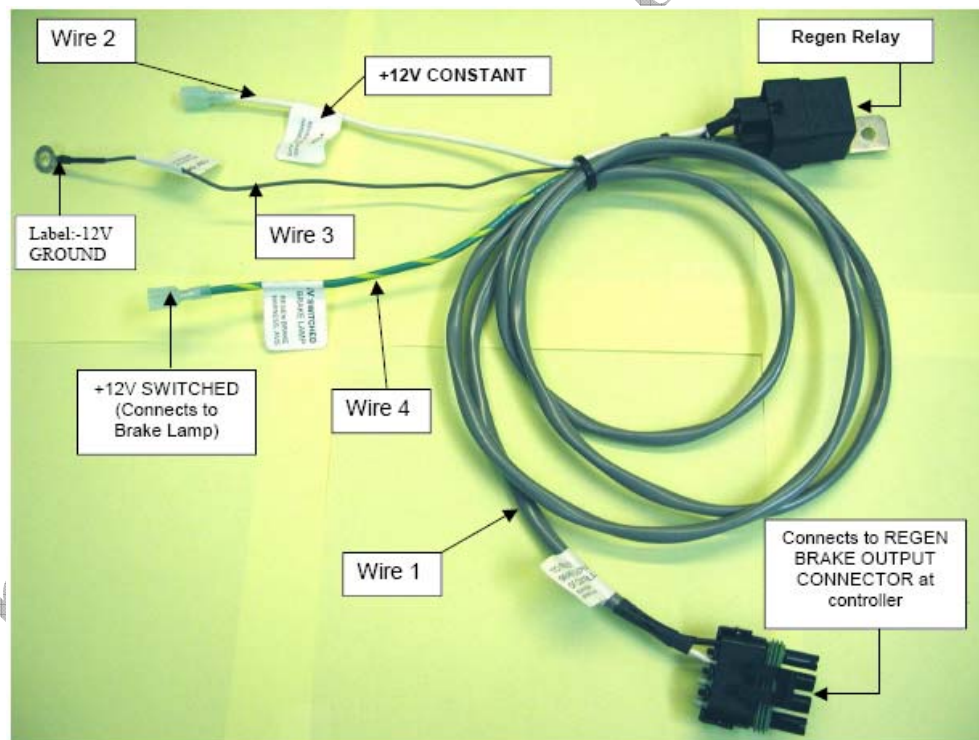
The table below summarizes the wiring of the Foundation Harness:

Signal	Source Connector	Pin	Cable Recommendation	Color/Stripe	Destination Connector	Pin
REGEN_DISABLE	AMP35	7	22 AWG 15 Cond Grey Shielded	red	AMP2F Plug	1
GND_D	AMP35	35	22 AWG 15 Cond Grey Shielded	SHIELD, black	AMP2F Plug	2
POWER_SAVER	AMP35	15	22 AWG 15 Cond Grey Shielded	green / black	AMP3F Plug	1
GND_A	AMP35	5	22 AWG 15 Cond Grey Shielded	green	AMP3F Plug	2
GND_A	AMP35	16	22 AWG 15 Cond Grey Shielded	black/white	AMP3F Plug	3
FORWARD-	AMP35	29	22 AWG 15 Cond Grey Shielded	red / white	Molex 3M Intl Plug	1
REVERSE-	AMP35	18	22 AWG 15 Cond Grey Shielded	green / white	Molex 3M Intl Plug	3
GND_D	AMP35	20	22 AWG 15 Cond Grey Shielded	blue	Molex 3M Intl Plug	2
SPEEDO_BUF	AMP35	25	22 AWG 15 Cond Grey Shielded	orange	PACKARD 1M	A
KEYED_12V_SRC	AMP35	1	18 AWG 2 Cond Grey	red	PACKARD 2M	A
KEYED_12V_SINK	AMP35	13	18 AWG 2 Cond Grey	black	PACKARD 2M	B
PEDAL_LO	AMP35	6	22 AWG 15 Cond Grey Shielded	blue / white	PACKARD 3F	A

ACCEL_PEDAL	AMP35	3	22 AWG 15 Cond Grey Shielded	white	PACKARD 3F	B
PEDAL_HI	AMP35	28	22 AWG 15 Cond Grey Shielded	white / black	PACKARD 3F	C
DRIVE_DISABLE-	AMP35	8	20 AWG 2 Cond Grey Shielded	grey	PACKARD 4F SQUARE	C
GND_D	AMP35	19	20 AWG 2 Cond Grey Shielded	SHIELD, black	PACKARD 4F SQUARE	D
BRAKE_LT_SRC	AMP35	14	18 AWG 2 Cond Grey	red	PACKARD 4M	C
BRAKE_LT_SINK	AMP35	24	18 AWG 2 Cond Grey	black	PACKARD 4M	D
Reserved	AMP35	all others				

5. Regen Brake Harness

The connections of the Regen Brake Harness are illustrated below.



6. Accelerator Pedal

In addition to the DMOC Interface Kit, Azure Dynamics offers a complete pedal assembly.

The pictures below show the accelerator pedal and pedal harness.



Notice the orientation of the black Pedal Cover.

To properly place the cover onto the pedal, simply take the bottom side (as seen in this picture) of the cover and roll it toward you. Then slide the cover onto the pedal.



Above is the proper routing of the Accelerator Pedal Cable. It is important that the cable be routed across the heel of the pedal and onto the opposite side of the pedal (in this picture the cable routes from the foreground to the left and then into the background).

This routing ensures that the movement of the pedal is applied as a twist to the cable rather than a bending of the cable (try operating the pedal with your hand to be sure that the cable twists at the heel and does not bend).