Eddy-10

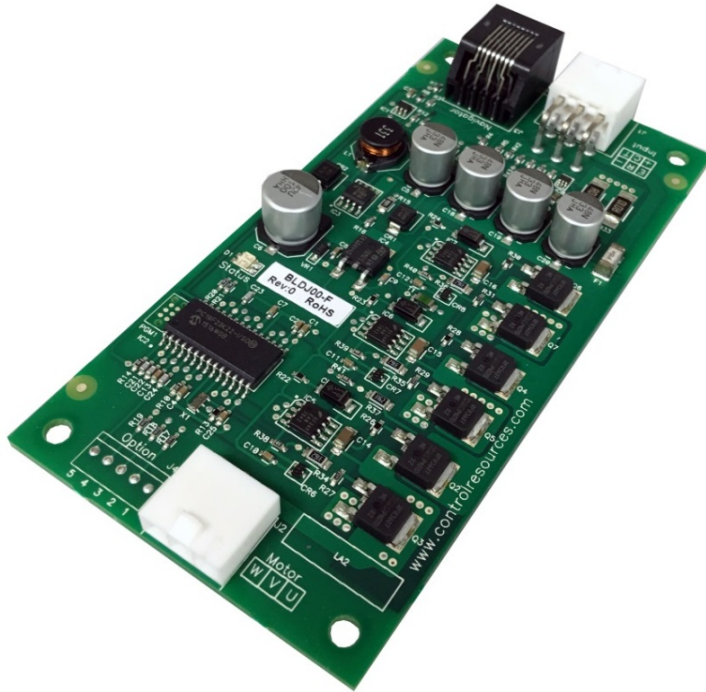## Programmable Brushless DC Motor Controller

Eddy-10 is an off-the-shelf, customer programmable controller designed for 24 and 48VDC BLDC motors rated up to 10 Amps. While no single controller can be used for every BLDC motor, the proprietary design of this six step trapezoidal sensorless control has been able to run all BLDC motors (within its power range) tested to date. The Eddy-10 can be customized for your application using the **Navigator** hand-held programmer (pictured above). The Navigator can be used to set a fixed speed or vary motor speed from a control input range (up to 10VDC). Other programming variables include; motor speed range, motor pole count, current /torque limits, acceleration / deceleration rates and motor on/off set points. Simply plug the Navigator into a powered Eddy-10 and scroll through the 17 variable menu, selecting the control inputs for your motor and application. Programmed profiles can be saved and copied to multiple controllers quickly and easily. The Eddy 10 also includes voltage, current, temperature protection and a status LED to give feedback in the event a fault does occur.

Part Number	Current Rating (55°C)	Description
BLD700-F	7 Amps	Eddy-10 Brushless DC Controller
BLDJ00-F	10 Amps	Eddy-10 Brushless DC Controller
H129-F	n/a	Eddy-10 Hardware Pack
PRG00-F	n/a	Navigator Hand Help Programmer

Specifications

- Power Source: 20-56VDC
- Approved Motors:
  - Brushless DC
  - 24VDC / 48VDC
  - 10A max up to 55°C: BLDJ00-F
  - 7A at 55°C/10A at 40°C: BLD700-F
  - 2–16 poles
- 15A fuse protection
- Speed Control Input: 0-10VDC
- Open loop, Closed loop or Fixed speed control
- Motor speed tolerance: ±2% at room temperature
- Dimensions (LxWxH) 4.8" x 2.4" x 0.68"
- Weight: 1.5 oz (42 grams)
- Operating Environment: -20 to 55°C, 0-95% RH

Customization Options

- Vertical Connectors
- Aluminum Enclosure
- Custom control inputs
- Sinusoidal wave forms
- Sensored designs
- Custom voltages and currents

Features

- Navigator Programmable variables
  - Motor pole count
  - Min & Max. motor speed
  - Min & Max. control signal
  - Motor ON/OFF set points
  - Ramp rate
  - Min & Max voltage lockout
  - Current Limits
- Navigator Monitoring Readings
  - Motor speed
  - Motor current draw
  - Controller temperature
  - Supply voltage
- Forward/Reverse contact closure
- On/Off contact closure
- Motor speed Tach signal output
- RoHS compliant
- On board Power/Fault LED
- Factory programming for orders of 50 units and up
- 2 year warranty
- Made in the USA

DIMENSIONS (fig. 1)
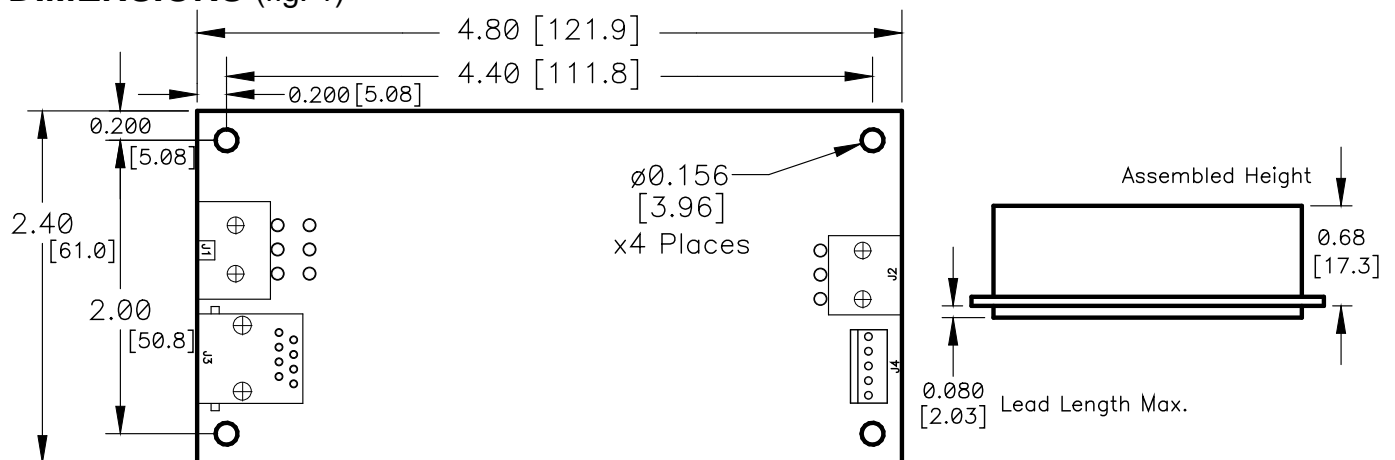
INSTALLATION

MOUNTING

To maintain safety and reliability, the Eddy-10 should be mounted in a ventilated enclosure so as to maintain an operating temperature of 55°C or less. Using the PCB supports specified in hardware pack H129-F (see below), or hardware of your choosing, mount the Eddy-10 on a flat surface using the four .156" (5.06mm) mounting holes. Note: To meet UL safety recommendations without using an insulator, the unit must be mounted .25" from a conductive surface.

Table 1: Recommended Hardware			
Header	H129-F Hardware Pack		
	Qty	Description	Mfg. & P/N
J1	1	Housing	Molex No. 39-01-2065
	6	Terminal	Molex No. 45750-1212
J2	1	Housing	Molex No. 39-01-4031
	3	Terminal	Molex No. 45750-1212
	4	PCB Support	Richco No. CBS-4-19

CONNECTIONS

Motor (J2)
Using hardware from the H129-F hardware pack (see table 1) or purchased from a third party, connect brushless DC motor (20-56VDC, up to 10Amps) to J2 using 16, 18 or 20 awg wire. Use wire size greater than or equal to that recommended by the motor manufacturer. If motor connections (U,V,W) are not labeled, connecting randomly will not harm the motor, however, the motor may run backwards. To change motor direction, swap 2 wires or reverse motor direction with a switch installed at J1 (pins -,R).

Power (J1, pin +,-)
Using hardware from the H129-F hardware pack (see table 1) or purchased from a third party, connect a 20-56VDC supply to J1 pin 3 (+) and pin 4 (-) using 16, 18 or 20 awg wire. Use wire size greater than or equal to that recommended by the motor manufacturer. Note: supply voltage and current need to be sized for the motor selected. Run current must not exceed 10 Amps.

Motor Reverse (J1, pin -,R)
To reverse motor direction, install a switch at J1 pins 4(-) & 5(R).

Motor ON/OFF (J1, pin -,E)
To turn motor on/off, add a switch across J1, pins 4(-) & 6(E). When open, motor will be ON, when closed, motor will be OFF.

Speed Control (J1, pin C,-)
To vary motor speed with a 0-10 VDC remote signal, connect + to J1, pin 2(C), connect – to J1, pin 4(-). See Navigator programming section to set minimum and maximum control inputs anywhere between 0-10VDC.

Motor Speed Monitoring (J1, pin T, -)
To monitor motor speed, connect a frequency measurement device to pin 1 (T). The output is an open collector with internal 10KΩ pull-up to 5VDC. See PROGRMMING section for details on PPR settings.

Connection diagram (fig. 2)
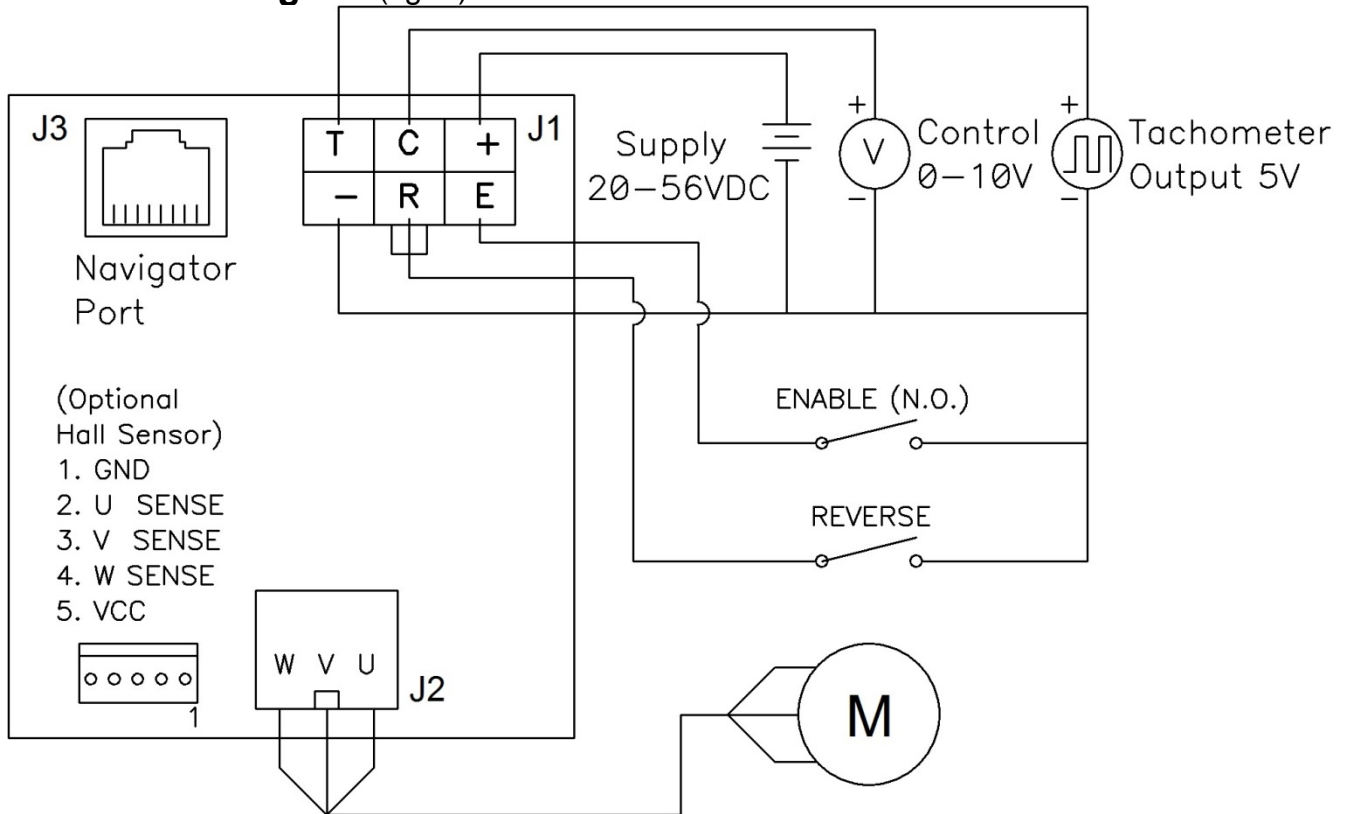
OPERATION OUT OF THE BOX

To take full advantage of the Eddy-10 capabilities, you will need the Navigator hand-held remote programmer PRG00-F. Out of the box, the Eddy-10 is preprogrammed to run most 4 pole, 24 or 48VDC brushless motors. Without additional programming and with no speed control input signal (J1, pin C), the motor (if capable) will run at 1,000 RPM (4 pole motor only) when power is first applied. You will also be able to turn the motor on or off, reverse direction and ramp the motor up to 5,000RPM (4 pole motor only) using the control inputs connected to J1 (see CONNECTIONS).
The status LED will also be fully operational (reference status LED operation below).

Status/Fault monitoring LED

The Eddy-10 automatically monitors motor speed, current, voltage and controller temperature and displays these through the Navigator. When the motor has been activated and a fault condition is sensed, this is also reported through the Status LED on the controller card. See Status LED fault key below. In fault conditions that shut the motor off, the default program will turn the motor back on only after the condition has cleared and power has been cycled. To program the motor to auto-restart after the fault clears, without cycling power, see Navigator programming section.

■ During **normal** operation, the Status LED will be solid green when power is applied.

■ An amber LED indicates a **soft current limit** has been sensed. The default soft current limit of 10A can be reduced using the Navigator.

■ A red flash 1 time indicates an **under voltage** condition causing the controller to automatically shut off the motor. Default under voltage is <20VDC, but can be increased using the Navigator.

■■ A red flash 2 times indicates an **over voltage** condition causing the controller to automatically shut off the motor. Default over voltage is >56VDC, but can be decreased using the Navigator.

■■■ A red flash 3 times indicates a **hard current limit** failure of 12A has been exceeded. When this occurs, the motor will automatically shut off.

■■■■ A red flash 4 times indicates a **temperature fault** of 110°C or more has been sensed on the controller card. When this occurs, the motor will automatically shut off.

■■■■■ A red flash 5 times indicates a **locked rotor** condition. When this occurs, the motor will automatically shut off.

Table 2: Programming Variables

Variable	Range	Default
Pole Count	2 - 16	4
Resolution	High / Low	Low
Control Mode	Closed Loop / Open Loop	Closed Loop
Start Voltage	1 – 16	8
Min Motor Volts	1 – 16	8
Tach PPR	(pole count dependant)	(pole count dependant)
Min & Max speed (closed loop)	See Table 3[1]	
Minimum speed (open loop)	0.0% - 100.0%[1]	0.0%
Maximum speed (open loop)	0.0% - 100.0%[1]	100.0%
Max. control input (VDC)	0.00 – 10.00[2]	10.0
Min. control input (VDC)	0.00 – 10.00[3]	2.0
Motor ON Input (VDC)	Disabled, 0.01 – 10.00[4]	Disabled
Motor OFF Input (VDC)	Disabled, 0.01 – 10.00[5]	Disabled
Ramp Time (seconds)	1 – 16 [6]	3
Alarm Response	Latched / Auto-restart	Latched
Current Limit (I_{Limit})	1 – 10	10
Minimum voltage (UVLO)	20 – 56	20
Maximum voltage (OVLO)	20 – 56	56

[1] It is valid to set the Minimum speed below the Maximum speed. This will result with the motor running slower as the input control voltage is increased.

[2] Maximum control input will not adjust below the Minimum control input setting.

[3] Minimum control input will not adjust below Motor On setting or above Maximum control input setting.

[4] Motor On will not adjust below Motor Off setting or above Minimum control input setting.

[5] Motor Off will not adjust above Motor On setting.

[6] In High Resolution Mode Ramp Rate range is 5 – 90 with a default value of 10

Table 3: Closed Loop Speed Settings

Motor Poles	Range (RPM)	Low Resolution Setting (RPM)			High Resolution Setting (RPM)		
		Default Minimum	Default Maximum	Step Size	Default Minimum	Default Maximum	Step Size
2	0 – 40,000	2,000	10,000	100.0	400	2,000	20.0
4	0 – 20,000	1,000	5,000	50.0	200	1,000	10.0
6	0 – 13,333	666	3,333	33.3	133	666	6.7
8	0 – 10,000	500	2,500	25.0	100	500	5.0
10	0 – 8,000	400	2,000	20.0	80	400	4.0
12	0 – 6,667	333	1,666	16.7	66	333	3.3
14	0 – 5,714	286	1,430	14.3	58	286	2.9
16	0 – 4,000	250	1,250	12.5	25	250	2.5

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PROGRAMMING

Initial Setup:
Connect Navigator to the Eddy-10 through the RJ45 connectors using the CAT5 cable supplied with the Navigator. Apply power to the Eddy-10 to enable programming via the Navigator. Navigator will display its current revision briefly then it will show it is connected.

```
    Eddy-10
    is ready
```
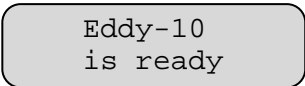
Pressing any of the four bottom keys will enter the Programming Menus.

❖ **Next**: Advances to the next menu
❖ **Previous**: Goes back to the previous menu
❖ ▲ or ▼: Selects choices within a menu
❖ **Write Drive:** Saves all the settings currently programmed in the Eddy-10. All programmed settings will be lost if power is removed before the write drive key is set.
❖ **Read Drive:** Reads the settings from the connected Eddy-10.
❖ **Save** and **Recall Program:** Stores and retrieves profiles stored in the Navigators internal memory.

Motor Settings:
The first six menus are used to describe the type of motor that will be connected to Eddy-10. Press the **Next** key to continue.

Pole Count Menu:

```
Set Pole Count
→ 4
```
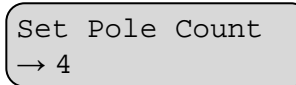
Pole count tells the controller how many magnet poles are in the motor so the Navigator menus will convert electrical RPM's to mechanical RPM's for the speed settings. Only even numbers are displayed from 2 – 16. Use the ▲ or ▼ keys to set the pole count for the motor connected then press the **Next** key to continue.

Warning: Pole Count can be changed later in the programming process, but doing so will automatically alter the the Tach PPR, Minimum Speed and Maximium Speed settings.

Resolution Menu:

```
Set Resolution
→ Low
```
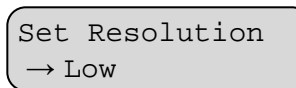
Eddy-10 has two resolutions for RPM control. High resolution measures RPM to 20 electrical cycles per minute while Low resolution measures RPM to 100 electrical cycles per minute. High resolution allows finer speed control (ref. table 3), but at a slower response rate. Use the ▲ or ▼ keys to toggle between High and Low resolution modes, then press the **Next** key to continue. **Caution:** The resolution may be changed at any time in the programming process, however doing so will automatically change the max. and min. speed already programmed.

Control Loop Menu:

```
Set Control Mode
→ Closed Loop
```

Eddy-10 can operate in closed or open loop control mode. In Closed Loop mode, Eddy-10 will adjust the duty cycle to maintain the desired RPM. In Open Loop mode, the Eddy-10 controls to a desired PWM duty cycle. In Open Loop mode the motor speed can be adjusted with supply voltage and inherently will not oscillate, while Closed Loop mode will maintain RPM under supply and load variations. Use the ▲ or ▼ keys to toggle between Open and Closed Loop modes then press the **Next** key to continue. **Caution:** The control mode may be changed at any time in the programming process, however doing so will automatically change the max. and min. speed already programmed.

Start Voltage Menu:

```
Start Voltage
→ 8 Volts
```

As with any sensorless BLDC controller, the initial start sequence is open loop. Eddy-10 allows setting the initial voltage applied to the motor between 1 – 16 Volts. A higher setting allows more load at start-up, but will draw more current than a lower setting. Use the ▲ or ▼ keys to adjust the desired voltage applied to the motor during initial start-up. Once the desired voltage is displayed, press the **Next** key.

Minimum Motor Voltage Menu:

```
Min Motor Volts
→ 8 Volts
```

The Min Motor Voltage ensures the motor spins fast enough to generate a usable signal for Eddy-10 to detect rotor position. Use the ▲ or ▼ keys to adjust the minimum voltage applied to the motor to prevent stalling. Once the desired voltage is displayed, press the **Next** key. Note: If the control loop is set to operate below this minimum voltage the output will remain at this voltage.

Tach Menu:

```
Set Tach PPR
→ 3PPR
```

Eddy-10 provides an open collector tachometer output which can be preset for 1PPR, 3PPR, or other selectable outputs. Use the ▲ or ▼ keys to adjust the desired PPR and press the **Next** key to continue.

Operational Menus:
Eddy-10 provides seven menus to adjust the operation of the drive for the application. A linear operation of speed vs. input (**ref. figure 3**) is provided until the slope between Min Speed and Max Speed is too steep for smooth operation. Once this high slope condition occurs Eddy-10 switches to a two-speed hysteretic control mode (**ref. figure 4**) to provide stable control. Change-over is automatic and is indicated in the lower right of the display by LIN for linear mode and 2Spd for hysteretic two speed control.

Minimum Speed Menu:

```
Set Min Speed
→   1000 RPM  LIN
```

Min Speed is the motor setting when the input control voltage is below the Min Input setting. In Closed Loop mode the setting will display in RPM's. In Open Loop mode the display will be in percent of duty cycle. If set above the Max Speed setting a negative slope will be implemented giving a decreasing motor speed for increasing control voltage. Use the ▲ or ▼ keys to adjust the Min Speed setting and press **Next** to continue.

Figure 3: Linear Operating Graph

Figure 4: Two Speed Operating Graph

Maximum Speed Menu:

```
Set Max Speed
→   5000 RPM   LIN
```

Max Speed is the motor setting when the input control voltage is above the Max Input setting. In Closed Loop mode the setting will display in RPM's. In Open Loop mode the display will be in percent of duty cycle. If set below the Min Speed setting a negative slope will be implemented giving a decreasing motor speed for increasing control voltage. Use the ▲ or ▼ keys to adjust the Max Speed setting and press **Next** to continue.
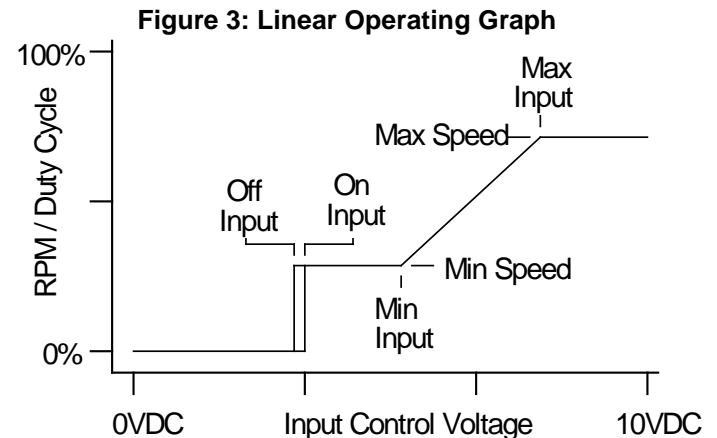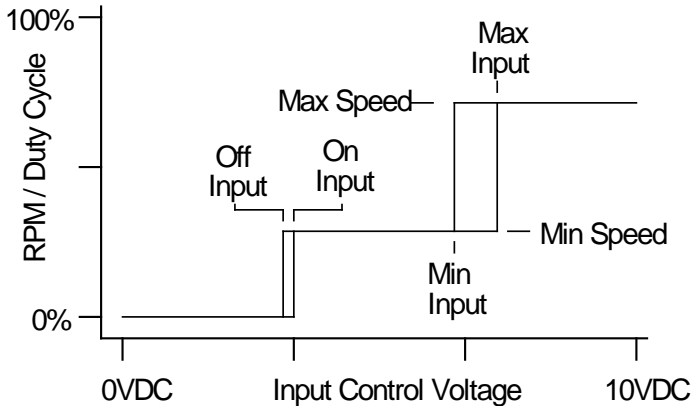
Max Input Menu:

```
Set Max Input
→ 10.00VDC   LIN
```

When the control input voltage rises above the Max Input setting the motor is set at the Max Speed setting. Below the Max Input setting the motor will start to decrease if in linear operation (Note: the mode is displayed in lower right). If in two speed mode, the input will remain at Max Speed until Min Input is reached. In two speed operation the hysteresis can be set by adjusting the Min and Max Input settings. If set far enough apart, the control mode will switch back to linear mode which will be indicated in the lower right display. The Max Input cannot be set below the Min Input setting. Use the ▲ or ▼ keys to adjust the Min Input setting and press the **Next** key to continue

Min Input Menu:

```
Set Min Input
→   0.00VDC   LIN
```

When the control input voltage falls below the Min Input setting the motor is set at the Min Speed setting. Above the Min Input setting the motor will start to rise if in linear operation (Note: the mode is displayed in lower right). If in two speed mode, the input will remain at Min Speed until Max Input is reached. In two speed operation the hysteresis can be set by adjusting the Min and Max Input settings. If set far enough apart, the control mode will switch back to linear mode which will be indicated in the lower right display. The Min Input cannot be set lower than On Input or higher than the Max Input setting. Use the ▲ or ▼ keys to adjust the Min Input setting and press the **Next** key to continue

On Input Menu:

```
Set On Input
→ Disabled
```

When the control input voltage rises above the On Input setting the motor is started. By setting to disable the control signal always powers the motor unless the Min Speed is set to 0. This setting does not affect the On/Off contact closure input. The On Input cannot be set lower than the Off Input or higher than the Min Input setting. Use the ▲ or ▼ keys to adjust the On Input setting and press the **Next** key to continue.

Off Input Menu:

```
Set Off Input
→ Disabled
```

When the control input voltage falls below the Off Input setting the motor is unpowered. By setting to disable the control signal always powers the motor unless the Min Speed is set to 0. This setting does not affect the On/Off contact closure input. The Off Input cannot be set higher than the On Input setting. Use the ▲ or ▼ keys to adjust the Off Input setting and press the **Next** key to continue.

Ramp Menu:

```
Set Ramp Time
 →  2 sec
```

Ramp time is how long the motor will take to climb from 0% power to full 100% power. The lower the setting the faster the acceleration applied to the motor. High resolution modes are limited to slower acceleration times than Low resolution mode. Use the ▲ or ▼ keys to adjust the Ramp Time setting and press **Next** to continue.

Note: If the pump speed is oscillating or overshooting, increase the Ramp Time until the condition corrects.

Limit Menus:
Eddy-10 allows limits to be set for input voltage limits and motor current to protect the motor from potential damage. As the drive can operate over a wide range without damage, the input voltage faults are only monitored when the motor is running and will not trigger when the motor is off. Motor current is always zero when the motor is not running.

Alarm Response Menu:

```
Set Alm Response
 → Latched
```

The alarm can be set to **auto-restart** the motor or **latch** the motor off in a fault condition until the fault is cleared and power is cycled. Use the ▲ or ▼ keys to toggle between Latched and Auto-restart. Press the **Next** key to continue.

ILimit Menu:

```
Set ILimit
 → 10.0 Amps
```

Once the ILimit current is reached no increases in output power is allowed. If the current continues to rise and reaches 0.5A above the ILmit the output voltage folds back to reduce the output current. ILimit function is indicated by the status LED changing from green to amber. This allows the user to set a torque limit to prevent motor or system damage due to high load. Note: Eddy-10 will shut down when the average current exceeds 10A, but controller damage could occur regardless of the ILimit setting if a current spike is fast enough. Use the ▲ or ▼ keys to adjust the ILimit setting for fold back current and press the **Next** key to continue.

UVLO Menu:

```
Set UVLO
 → 20 VDC
```

Once the motor is active, the input voltage is monitored. If the input voltage drops below the UVLO setting, the motor is stopped and a fault displayed on the Status LED. Recovery is determined by the Alm Response setting. Use the ▲ or ▼ keys to adjust the UVLO setting and press the **Next** key to continue.

OVLO Menu:

```
Set OVLO
 → 56 VDC
```

Once the motor is active, the input voltage is monitored. If the input voltage rises above the OVLO setting, the motor is stopped and a fault displayed on the Status LED. Recovery is determined by the Alm Response setting. Use the ▲ or ▼ keys to adjust the OVLO setting and press the **Next** key to continue.

Warning: Voltages above 56 can damage the controller regardless of the OVLO settings.

Monitor Menus:
Eddy-10 provides monitor capabilities to indicate motor speed, motor current, controller temperature, supply voltage, motor status, and fault conditions. Note that no adjustments are allowed in the Monitor menus as these are read only variables. The **Write Drive, Read Drive, Recall Program,** and **Save Program** keys are not active in these menus. The **Next** and **Previous** only keys are used to change between screens.

Motor Speed/Current

```
Speed:      0 RPM
Current:  0.0 A
```

Speed is given in RPM Current is displayed in 0.1A resolution.

Temperature/Supply

```
Temp: 25°C
Supply: 24 VDC
```

Temperature is in °C from 0 – 127. The supply voltage is displayed in volts DC.

Motor Status

```
Motor Status:
Off
```

```
Motor Status:
Running Fwd
```

The motor status indicates the current direction of the motor and whether it is running or stopped.

Fault Status

The Fault Status screen will indicate all the active fault flags in the Eddy-10. Description for the various fault indicators are given in the Table 4 below:

Table 4: Alarm Conditions

Navigator Display	LED Flashes	Description
UVLO	1	Supply < UVLO limit setting.
OVLO	2	Supply > OVLO limit setting
ITrip	3	Average current > 12A Peak current > 15A
OTmp	4	Board sensor > 110°C
Stall	5	Commutation detected locked rotor.

Copy Program Operation:

Connect Navigator to the Eddy-10. Apply power to the Eddy-10 to enable programming via the Navigator. Navigator will display its current revision and product type it is connected to as shown below.

```
    Eddy-10
   is ready
```

Press **Read Drive** and the display will indicate when it is ready with the screen below.

```
Drive parameters
read
```

Disconnect the Eddy-10 and connect the next Eddy-10 to program. When the Navigator recognizes this Eddy-10, press **Write Drive.** Do not press any adjust keys or Navigator will upload the target Eddy-10's parameters instead of loading the previously saved program. Once the Eddy-10 has been programmed the message below will appear.

```
Drive parameters
written
```

Write Drive step above can be repeated for any number of Eddy-10 products.

Profile Memory Functions:

Navigator can save up to 16 separate profiles for each product type it supports for later use. Each profile can be named with a 12 character label.

To save a profile, connect Navigator to the Eddy-10 and apply power. Then adjust the parameters to the desired settings and press **Save Program.**

```
Select program
 →Profile A
```

Navigator will ask which profile to save the settings in. Use the ▲ or ▼keys to select which profile name to use. If custom names have been previously set they will also display as such in this list. Press **Next** to continue or **Previous** to quit the save operation.

Navigator will allow the profile names to be customized. Use the **Previous** and **Next** keys to select which character to modify and use the ▲ or ▼ keys to change the characters value. Once the label is correct, press **Save Program** again and Navigator will store the profile to its memory.

```
Set label
 →Profile A
```

Note: A blank character is between the ← and ! characters.

Recalling a profile:

To recall a previously saved profile, connect Navigator to the Eddy-10 and apply power. Then press **Recall Program.**

```
Select program
 →Profile A
```

Navigator will ask which profile to recall the settings from. Use the ▲ or ▼keys to select which profile to use. Press **Next** to recall the profile listed or **Previous** to quit the recall operation.

Navigator is now ready to write to a drive or modify the recalled profile's parameters. Once all parameters are correct, press the **Write Drive** key to save the settings in the Eddy-10.

Navigator Troubleshooting:
Navigator automatically verifies the type and version of the connected Eddy-10. It can display prompts to help the user identify possible problems.

```
Can't connect
Pls check wiring
```

Indicates the Navigator cannot receive any valid data. It is possible some wires or contacts are damaged, or the Eddy-10 revision is not compatible with Navigator.

```
Please update
programmer.
```

Indicates the Navigator has found an Eddy-10, but the Eddy-10 revision is newer than the Navigator firmware supports. Navigator includes an upgrade port for future updates.

```
Older drive need
previous codes
```

indicates the Navigator has found an older version of the Eddy-10 that is no longer compatible with its current firmware. The upgrade port can be used to load an older version of firmware to update the Eddy-10, or it may be possible to update the Eddy-10 to the newer version.

PERFORMANCE TROUBLESHOOTING

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Symptom	Solutions
Motor fails to start	1) If motor make high pitch noise but doesn't turn increase the Motor Start Voltage. 2) If motor turns, but makes excessive noise and/or takes excessive current decrease the Motor Start Voltage or increase Ramp Time.
Motor stalls or stops	1) Ensure Motor Enable input is not tied low (motor off). 2) Ensure control voltage is not below Off Input setting. 3) Check Status led or fault screen for possible fault. - UVLO: Increase supply voltage. - OVLO: Decrease supply voltage. - Over temp: Increase airflow or improve cooling to board. - Stall: Remove any mechanical jam of motor. Increase Min Motor Voltage. 4) Check if F1 fuse is open. 5) Check all motor connections.
Motor fails to reach full speed	1) Check Status led for amber indication – increase ILimit setting. 2) Eddy-10 drops approximately 2% from supply – increase supply voltage if possible.
Motor speed doesn't match Navigator RPM reading	1) Verify Pole count is correct.
Motor speed oscillates	1) Increase Ramp Time. 2) Check with Open Loop Mode if possible.
Settings don't save	1) Press Write Drive before cycling power. Note Write Drive is not available in the monitor only menus.

*Eddy-10 is designed to operate with a wide range of motors and can be customized for even more applications and motor types. Please contact Control Resources for details.