



DRF

Digital Closed Loop Proportional Valve Controller

The DRF is a compact, DIN-rail mounted controller for use with proportional solenoid valves. The DRF can be set to operate in open loop (current feedback) mode or closed loop (external feedback) mode. In open loop mode the controller provides current to a valve coil in proportion to an input signal. In closed loop mode the controller uses external feedback to maintain a velocity or position proportional to an input signal. The loop closure utilizes industry standard PID control algorithms. Bright LED indicators on the front of the unit provide an overview of the operating status. Setup is accomplished through a convenient hand held interface or a PC. Once configured, the settings are stored in permanent memory within the unit. The DRF enclosure features convenient DIN-rail mounting and removable terminal blocks.

- Easily configured using WhiteOak Terminal software or our hand held interface
- LED indication of power, output current and fault status
- Compact DIN-rail mount housing
- Multiple modes for single and dual coil applications, with or without enable
- Input options include -10V to 10V and 0 to 20mA
- All input and output limits are independently adjustable
- Adjustable current limited output with short circuit protection
- +10 and -10 volt references for potentiometer/joystick controls on +/-10V analog units
- Adjustable ramp up and ramp down rates
- Selectable dither frequency up to 1000 Hz
- Microprocessor controlled for consistent, reliable performance



Operating Specifications:

Supply Voltage	9 to 32VDC
Supply Current	I _{SOL} + 50mA
Output Current	DRF-x06: 600mA MAX. DRF-x12: 1.2A MAX. DRF-x25: 2.5A MAX.
Solenoid Resistance	2Ω MIN.
Reference Voltages	+10V, -10V @ 20mA (DRF-Vxx versions only)
Dither Settings	30, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 1000 Hz
Analog Input Range	DRF-Vxx: -10V to 10V DRF-Axx: 0 to 20mA
Analog Input Impedance	DRF-Vxx: 38kΩ DRF-Axx: 250Ω
Analog Input Resolution	10 bits
Operating Temperature Range	-20° to 70° C
Enclosure	Polyamide
Dimensions	Inch: 0.69 W x 4.50 H x 4.30 D mm: 17.5 W x 114.5 H x 109.4 D

WARRANTY INFORMATION, PERFORMANCE ASSURANCE, AND APPLICATION LIMITATIONS

Limited Warranty

WhiteOak Controls, Inc. warrants its products free from defects in material, workmanship, and design for a period of one year after installation, provided the installation date is less than one year after manufacture. In no instance is there any warranty of fitness for a particular use and WhiteOak Controls, Inc. cannot and does not accept responsibility of any type for any of its products that have been subjected to improper installation, improper application, negligence, tampering, or abuse, or which have been repaired or altered outside of the WhiteOak Controls factory. WhiteOak Controls' liability under this warranty shall extend only to replacement or correction, f.o.b. our factory, of any defective part or product determined by inspection as not conforming to this warranty. We make no other warranties, expressed or implied, and are not responsible for any consequential damages resulting from use by any buyer or user, our liability being limited to the value of product sold or obligation to replace a defective part.

Performance Assurance

All WhiteOak Controls products are individually tested at the factory to perform as indicated in all applicable sales and technical documentation. However, assurance of suitability of all WhiteOak Controls products in the buyer's application is the responsibility of the buyer. Such assurance would typically include the manufacture of a prototype followed by a test or qualification program on the part of the buyer.

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- Any product that comes under the Federal Highway Safety Act, namely steering or braking systems for passenger-carrying vehicles or on-highway trucks.
- Aircraft or space vehicles.
- Ordnance equipment.
- Any end product that, when sold, comes under the U.S. Nuclear Regulatory Commission rules and regulations.

Specific written approval for any application of WhiteOak Controls products in any of the above named applications should be obtained from WhiteOak Controls, Inc. Consultation with WhiteOak Controls distributors or factory engineers is advised in unusual situations where applicability is questionable.



DRF

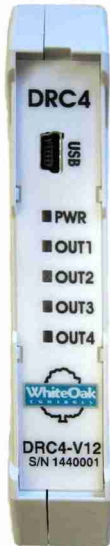
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Physical Description

The DRF is shown at the right. There are four indicator lamps labeled PWR and OUT1 through OUT4 (for the four channel controller). The PWR lamp will light green whenever power is applied to the unit and is within the specified voltage range. Under normal operation the OUTx lights will provide an indication of the current being supplied to the solenoid output for a given channel. The lights will be yellow and the brightness will vary with the output current. In the case of a fault the light will flash red with a flash code corresponding to the type of fault for that channel.

Communication with the DRF takes place through the USB port. The port allows for configuration and monitoring of the operating parameters.

Note: When connected to a PC, the DR controller will be recognized as a USB device with or without power applied to the controller. However, to configure the controller it must be powered.



User Interface

The DRF has a number of internal settings which allow each unit to be configured for the application in which it is used. These settings are accessed with a PC running Windows based WhiteOak Terminal software or with the WhiteOak Hand Held Interface

WhiteOak Terminal provides a convenient interface to the DRF. The program gives the user the ability to view and make changes to the configuration. It also allows the user to store complete configurations in files on the PC. These files can then be recalled to program new units or update existing ones.

The hand held interface is a stand-alone option. Because it is fully self-contained, the programmer, cable and adapter are all that is required. This is a good alternative for field installations where a PC might not be convenient.

Configuration

All interface operations are accomplished with the use of 4 buttons. The buttons are Lock, Unlock, Up, and Down. The hand held interface represents these in graphical form as padlocks and arrows. The same symbols are used on the buttons in WhiteOak Terminal and can be activated with the mouse. The program also recognizes short-cut keys. The keys used are '/'(lock), '*'(unlock), '+'(up), and '-'(down).

The data displays for both methods are very similar. The hand held interface has a two-line LCD display. The display is represented graphically in WhiteOak Terminal.

The up and down arrows are used to navigate through the parameter list. When either button is pressed the display will be updated with the next parameter in the list. The parameter name will appear on the first line and the associated setting will appear on the second line. The list is accessed in a circular fashion, stepping down from the last parameter to the first and vice-versa.

There are three types of parameters in the list: fixed; monitor; and variable. Fixed parameters are used to show things such as the module's firmware version number. Fixed parameters do not change. Monitor parameters display things such as output current or system voltage. These parameters are constantly updated when the module is functioning. Variable parameters are those which can be changed by the user in order to configure the module. Examples of this type are operating mode and maximum output current. For convenience, some parameters combine variable and monitor types on one line. This allows the user to set a variable according to the current monitor value.

To change the setting of a variable parameter, the user must press the unlock button to place the system in edit mode. While in edit mode the display will show an asterisk (*) at the beginning of the second line. In edit mode the up and down buttons are used to change the value of the parameter. For parameters which contain both variable and monitor data, the monitor data is shown surrounded by square brackets. Pressing the unlock button again while in edit mode will immediately load the current monitor value into the variable. Once the desired setting is displayed, pressing the lock button will save the parameter and end edit mode.

Parameter List

The following table outlines the parameter list for the DRF. Along with the name of the parameter, the table lists the limits and units for each item.

Parameter	Limits	Units
DRFx-xxx		Version #
C1 MODE	See Mode Description	Mode #
C1 PROPORTIONAL	0.0 to 100	%
C1 INTEGRAL GAIN	0.0 to 100	%
C1 DERIVATIVE	0.0 to 100	%
C1 PID LOOP TIME	1 to 30	cycles
C1 DEADBAND	0.0 to 2.0	V (mA)
Previous 5 parameters repeated for channel 3 ²		
C1 MIN INPUT	-10 to +10.0 (0 to 20.0)	V (mA)
C1 MAX INPUT	-10 to +10.0 (0 to 20.0)	V (mA)
C1 MIN OUTPUT	0 to 600 ¹	mA
C1 MAX OUTPUT	0 to 600 ¹	mA
C1 RAMP UP	0.0 to 120.0	Seconds
C1 RAMP DOWN	0.0 to 120.0	Seconds
Previous 6 parameters repeated for all channels ²		
DITHER FREQ.	OFF to 300	Hz.
C1 COMMAND INPUT		V (mA)
C1 OUTPUT CURRENT		mA
Previous 2 parameters repeated for all channels ²		
SUPPLY VOLTAGE		Volts
FAULT STATUS		Fault

¹0 to 1.2 A for -12A version, 0 to 2.5 A for -25A version

²Parameters shown starting with C1 are repeated for each channel as shown and are displayed as C2 to C4

DRFx-xxx - This is the title parameter. The model number of the unit and the firmware version are displayed. The title parameter is fixed.



DRF

Digital Closed Loop Proportional Valve Controller

Cx MODE – There are up to four modes of operation for the DRF controller. The different modes allow for many combinations of open and closed loop, use of the enable input and paired outputs. The following table describes the different modes and which channels they can be applied to:

Mode	Enable	Channels
1 CUR NO ENBL		1,3
2 CUR USE ENBL	X	1,3
3 VEL NO ENBL		1,3
4 VEL USE ENBL	X	1,3
1 IN2 NO ENBL		2,4
2 IN2 USE ENBL	X	2,4
3 IN1 NO ENBL		2,4
4 IN1 USE ENBL	X	2,4

Open Loop Modes – For channels 1 and 3, modes 1 and 2 are the open loop or current controlled modes. Modes 3 and 4 are the closed loop velocity (or pressure) modes and are described below. For channels 2 and 4, modes 1 and 2 utilize that channel's input. Modes 3 and 4 utilize the input from the previous channel to allow them to be paired with channels 1 and 3 respectively to drive two outputs from one command signal. As an example, to drive a directional proportional valve with outputs 1 and 2, C1 Mode could be set to mode 1 and C2 Mode could be set to mode 3. The input range should then be set such that they do not overlap. Further examples are found in the applications section.

Closed Loop Modes – The closed loop modes 3 and 4 employ the velocity mode PID algorithm. Velocity mode is typically used with flow controls or pressure relief valve. The closed loop modes are only available for channels 1 and 3. When one of these modes are selected, the channel 1 or 3 input is used as the command while the channel 2 or 4 input is used as feedback. Only the channel 1 or channel 3 output will be used. The associated channel's mode setting is not used.

PROPORTIONAL - The Proportional parameter sets the proportional gain in the control loop. The proportional gain represents the P term in a PID control loop. The proportional term is simply a multiplication of the error which is added to the output. The Proportional parameter is a variable type.

INTEGRAL GAIN – Integral Gain is used to determine the integral or I term in the PID control loop. The integral term is a cumulation of error over a period of time. The integral term is generally used to overcome an offset in the output or to correct for very small deviations over time at a fixed command. The Integral Gain parameter is a variable type.

DERIVATIVE - The Derivative parameter sets the derivative gain in the control loop. The derivative gain represents the D term in a PID control loop. The derivative term is the rate of change of the error. The derivative term is generally used to increase the responsiveness of a system. The Derivative parameter is a variable type.

PID LOOP TIME – PID Loop Time represents the PID loop closure time in number of dither cycles. Therefore, the lower the number, the more quickly the system will respond to error. The PID Loop Time parameter is a variable type.

DEADBAND – Deadband represents the error tolerance allowed by the PID loop. When the magnitude of the error is less than the Deadband, the control loop stops correcting. For a velocity loop this means the output will remain at a fixed level. For a position loop both outputs will remain off. The PID Loop Time parameter is a variable type.

Cx MIN INPUT - The Min Input parameter is used to establish the command corresponding to the minimum output for open loop modes. The Min Input can be greater than the Max Input if an inverted input/output profile is desired. For closed loop modes, the Min Input sets the lower boundary for scaling which will correspond to the Min Input for the paired channel on the transfer profile. Also for closed loop modes with inverse function valves, the feedback minimum must be set higher than the feedback maximum. See the Applications section for examples. The value shown in square brackets is the current analog command value for this channel. The Min Input parameter is a combination variable/monitor type.

Cx MAX INPUT - The Max Input parameter is used to establish the command corresponding to the maximum output for open loop modes. The Max Input can be less than the Min Input if an inverted input/output profile is desired. For closed loop modes, the Max Input sets the upper boundary for scaling which will correspond to the Max Input for the paired channel on the transfer profile. Also for closed loop modes with inverse function valves, the feedback minimum must be set higher than the feedback maximum. See the Applications section for examples. The value shown in square brackets is the current analog command value for this channel. The Max Input parameter is a combination variable/monitor type.

Cx MIN OUTPUT - The Min Output parameter represents the minimum current of the output. This is similar to the dead band setting on amplifiers with combined input/output settings. The value displayed represents the current in milliamps (amps for -12A,-25A). The value shown in square brackets is the real time output current for this channel. The Minimum Output parameter is a combination variable/monitor type.

Cx MAX OUTPUT - The Max Output parameter represents the maximum current of the output. This is similar to the gain setting on amplifiers with combined input/output settings. The value displayed represents the current in milliamps (amps for -12A,-25A). The value shown in square brackets is the real time output current for this channel. The Maximum Output parameter is a combination variable/monitor type.

Cx RAMP UP/DOWN – Ramp Up and Ramp Down are used to limit the rate of change of the input command signal, and therefore the ramp time of the output. **The Ramp settings represent the amount of time in seconds required to ramp through the full input range.** Therefore, the time required to ramp from one command level (CMD1) to another (CMD2) can be calculated by $T = \text{Ramp} * (\text{CMD2} - \text{CMD1}) / 20$. When the input is increasing, the Ramp Up setting is used. When the input is decreasing, the Ramp Down setting is used. The Ramp Up/Ramp Down parameters are variable.



DRF

Digital Closed Loop Proportional Valve Controller

DITHER FREQ. - The Dither Frequency parameter has 13 options for dither control. The choices are 30, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, and 1000 Hz. Dither control provides low frequency modulation which is required in many proportional valve applications. In the DRF controller the Dither Frequency is equal to the PWM frequency. The Dither Frequency parameter is variable.

Cx COMMAND INPUT – Command Input displays the real time input being supplied to this channel. The Command Input parameter is a monitor type.

Cx OUTPUT CURRENT - Output Current displays the nominal current being supplied to the output. The Output Current parameter is a monitor type.

SUPPLY VOLTAGE - The Supply Voltage parameter displays the module's power supply voltage. This value is included as an aid to troubleshooting. The Supply Voltage parameter is a monitor type.

FAULT STATUS - The Fault Status parameter displays the current fault code or codes when one or more faults exist. The two faults are Open Output and Output Short. The Fault Status parameter is a monitor type and will scroll through the faults if more than one exist. In addition to the on-screen fault status, the STATUS light will flash red indicating a problem. The light will flash a number of times periodically corresponding to the type of fault with 2 flashes for Open Output and 3 flashes for Output Short.

PID Algorithm

The controller uses a digital, velocity style PID algorithm as shown:

$$O(t) = O(t-1) + P * (e(t) - e(t-1)) + I * T * e(t) + D / T * (e(t) + e(t-2) - 2 * e(t-1))$$

Where:

- O = output
- P = proportional gain term
- I = integral gain term
- D = derivative gain term
- e(t) = error at time t
- T = PID loop time

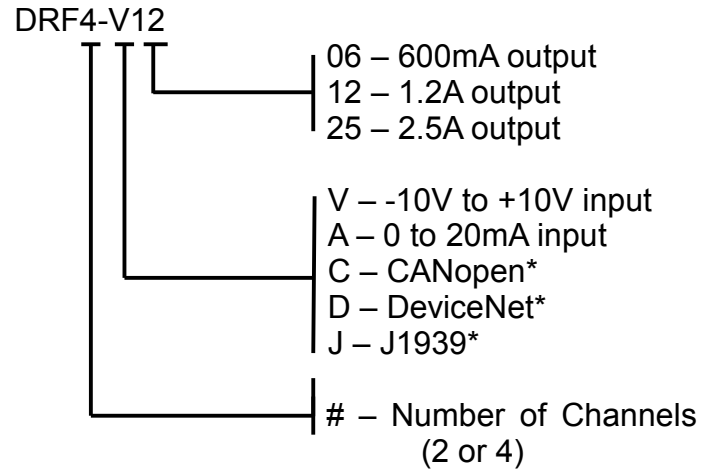
Setup Procedure

The following steps are recommended when commissioning a GC60 controller:

1. Select the desired operating frequency.
2. Set the Minimum and Maximum Outputs according to the valve data sheet.
3. Set the Dither Frequency as recommended by the valve manufacturer. Higher dither frequencies can sometimes be used in closed loop systems to improve frequency response.
4. Adjust the PID parameters as needed to optimize the system response. Start with Proportional only to achieve a stable system. Then add Integral and finally Derivative as needed to improve system response and/or stability.

Ordering Information

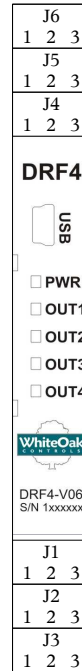
The following is a break down of the DRF part numbering system:



*Future product

Wiring

Terminal functions are listed in the table below. Following the table are application examples for various modes of operation.



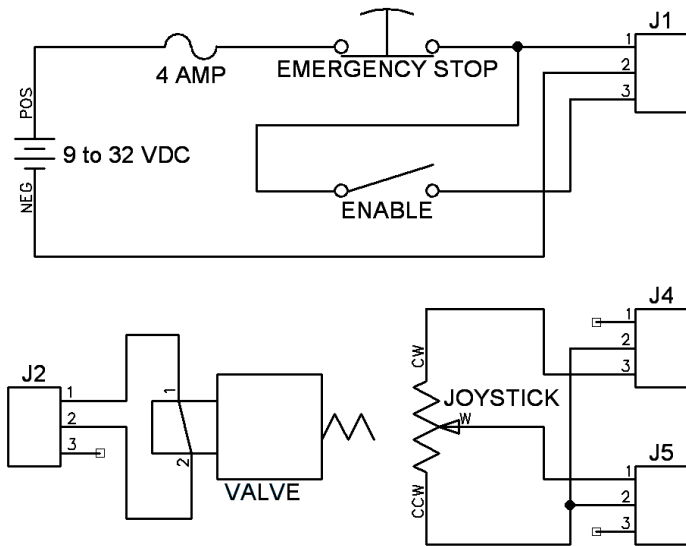
Terminal	Function
J1-1	+V Supply
J1-2	Supply Common
J1-3	Enable Input
J2-1	Output Ch. 1
J2-2	Common
J2-3	Output Ch. 2
J3-1	Output Ch. 3
J3-2	Common
J3-3	Output Ch. 4
J4-1	-10V Reference
J4-2	Common
J4-3	+10V Reference
J5-1	Command Input Ch. 1
J5-2	Common
J5-3	Command Input Ch. 2
J6-1	Command Input Ch. 3
J6-2	Common
J6-3	Command Input Ch. 4

Applications

Open Loop Single Solenoid Joystick Control (DRF1-Vxx)

The DRF can be controlled with a joystick or potentiometer as shown. The recommended potentiometer value is 10kΩ. Mode 1 may be used rather than Mode 2 if the enable is not used. The Min Input and Max Input may be exchanged for inverse operation. Dither and Output settings will vary depending on the valve and application.

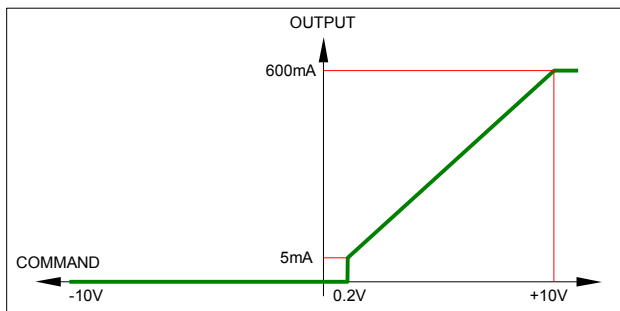
Schematic:



Example Settings:

Parameter	Value
C1 Mode	2 CUR USE ENBL
C1 MIN INPUT	0.2 V
C1 MAX INPUT	10.0 V
C1 MIN OUTPUT	5 mA
C1 MAX OUTPUT	600 mA
C1 RAMP UP	1 S
C1 RAMP DOWN	1 S
DITHER	150 Hz.

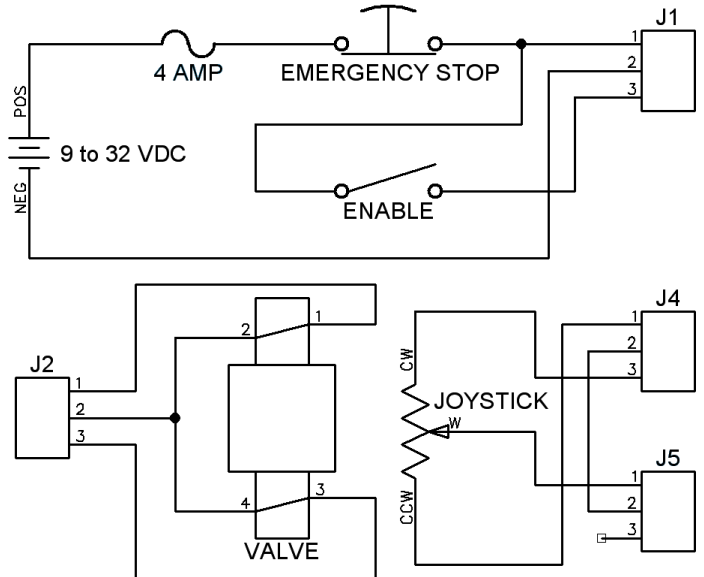
Input/Output Diagram



Open Loop Double Solenoid (DRF2-Vxx)

The DRF can be setup to drive a double solenoid valve using one command as shown in the following diagram. If enable is not used, C1 Mode should be set to 1 and C2 Mode to 3. The minimum input parameters for the two channels must be set such that both outputs will not be active with the same input signal. The settings do not have to be the same or mirrored between the two channels as shown in the example though in many cases they will be. Dither and Output settings will vary depending on the valve and application.

Schematic:



Example Settings:

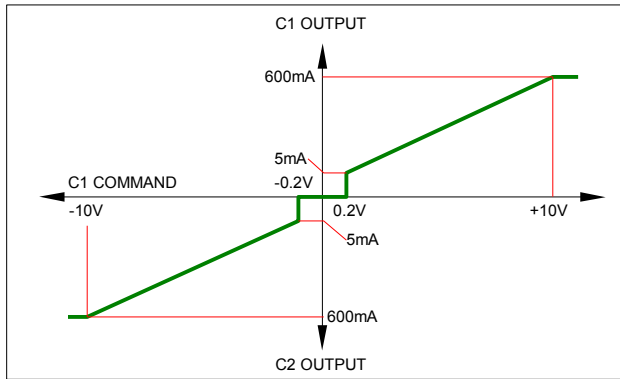
Parameter	Value
C1 MODE	2 CUR USE ENBL
C1 MIN INPUT	0.2 V
C1 MAX INPUT	10.0 V
C1 MIN OUTPUT	5 mA
C1 MAX OUTPUT	600 mA
C1 RAMP UP	1 S
C1 RAMP DOWN	1 S
C2 Mode	4 IN1 USE ENBL
C2 MIN INPUT	-0.2 V
C2 MAX INPUT	-10.0 V
C2 MIN OUTPUT	5 mA
C2 MAX OUTPUT	600 mA
C2 RAMP UP	1 S
C2 RAMP DOWN	1 S
DITHER	150 Hz.



DRF

Digital Closed Loop Proportional Valve Controller

Input/Output Diagram



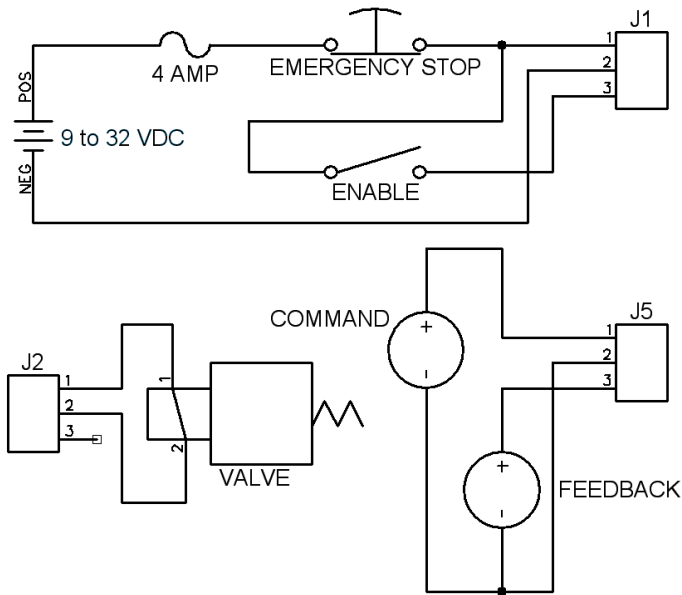
Example Settings:

Parameter	Value
C1 MODE	4 VEL USE ENBL
C1 MIN INPUT	0.2 V
C1 MAX INPUT	10.0 V
C1 MIN OUTPUT	5 mA
C1 MAX OUTPUT	600 mA
C2 Mode	1 CUR NO ENBL
C2 MIN INPUT	0.2 V
C2 MAX INPUT	10.0 V
C2 MIN OUTPUT	5 mA
C2 MAX OUTPUT	600 mA
DITHER	150 Hz.

Closed Loop Velocity Mode (DRF2-Vxx)

The following example shows a DRF setup to drive a single solenoid valve in closed loop velocity mode. Dither and Output settings will vary depending on the valves and the application. Input ranges should be adjusted to match the desired command range and working feedback range. **NOTE:** The feedback (C2 input) min must be greater than max for use with inverse operation valves where no current results in maximum flow or pressure.

Schematic:



Command/Feedback Transfer Diagram

