Proportional Amplifiers and Ancillary Products

Sun Amplifiers, Hand Held Controllers, Set-up Procedures, Accessories, and Trouble Shooting Guides

Proportional Amplifiers and Ancillary Products

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Sun Hydraulics Technical Tips

1. Amplifier Overview

Proportional valve amplifiers are devices that interpret an analog command and control electrical power to a proportional solenoid coil. This scenario is shown graphically in Figure 1. Analog commands are typically a voltage between 0 and 10 VDC or a current between 0 and 20 mA (4 to 20 mA is more common). Proportional amplifiers are used to:

- Control the amount of current supplied to the coil which controls the solenoid force
- Set the minimum and maximum pressure or flow
- Set the ramp times from minimum to maximum command
- Adjust the dither (PWM) to maximize performance

Coil power could be controlled directly using a rheostat (a high power potentiometer) for instance, but power is wasted, heat is generated, and valve performance will suffer without dither and current feedback as provided by a well engineered amplifier. Specifically, the valve performance will not be repeatable nor will the hysteresis be within published tolerances. So, for maximum energy efficiency and operational performance, a proportional amplifier is highly recommended.

Some advantages of using the Sun proportional amplifier are:

- Sun amplifiers include an internal closed loop current feedback feature which maintains consistent current to the solenoid coil. As electrical power flows through the copper windings of a coil, the copper heats up, which increases the resistance of the copper to current flow. As solenoid force is directly related to coil current, if current varies, then force and valve performance will also vary. The internal closed loop control on current ensures consistent operation and good repeatability.

- Traditionally, proportional valve amplifiers are tuned with a screw driver turning a potentiometer. With Sun amplifiers, the tuning is accomplished via an infrared (IR) adapter and either a hand held programmer (HHP) or the Sun Hydraulics Amplifier Set Up software package for PCs. There is no need for a screw driver, digital volt meter or multimeter (DVM), or oscilloscope. The proportional amplifier, once set and initially powered, remembers the necessary information to control the valve. The HHP or PC cable can then be removed and stored away. The combination of the IR adapter plus HHP or software, creates a precise and easy to use "electronic screw driver".

- Performance data shown on the Sun website for proportional valves is based on the use of Sun amplifiers.

- Only Sun amplifiers are specifically designed to operate Sun coils on Sun valves. *(While other makes of amplifiers will control Sun proportional valves, performance may vary greatly!)*
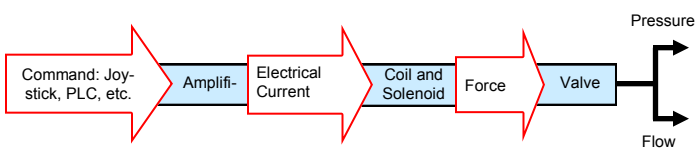

Figure 1.
How it all works overview.

2. Sun Proportional Amplifier Types

Sun provides two main amplifier types:

- An embedded electronics amplifier
- A plug-on mount amplifier

Embedded Electronics Amplifier Model(s) 790-***** with Integral Coil

Figure 2 shows the embedded amplifier construction which includes an electronic amplifier board, connector housing and integral coil. The electronic board, housing and coil are assembled and ultrasonically welded together. The three pieces are then encapsulated with potting compound to form a sealed assembly.
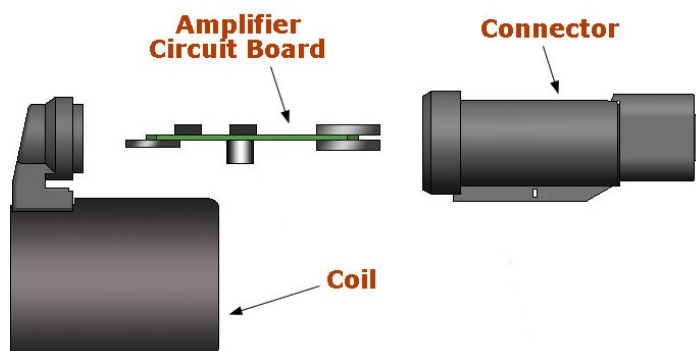

Figure 2.
Embedded amplifier construction
(potting compound not shown).

Figure 3 shows a typical embedded electronics amplifier and HHP combination ready for set-up programming.

Figure 3.
Embedded amplifier ready for set-up.

Model 790 amplifiers are available with either DIN or Deutsch connector interfaces. The DIN interface is widely available and very popular with system builders. The Deutsch interface provides IP69K environmental protection and is preferred for mobile and outside applications exposed to the weather or wash down.

Numerous voltage/current options are available as well as power saver and ramping function options. Additionally, Sun can factory set an embedded amplifier and valve combination to precise customer requirements.

Plug-On Mount Model(s) CV*-*** with Integrated Cable (Information is provided for service only. Plug-on amplifiers are no longer sold by Sun Hydraulics)

Models C1V and C2A amplifiers are available with DIN connector interfaces only and are recommended for "benign" environments. Four different voltage/current options are available for this type of amplifier. The plug mount model may be used on any of Sun's standard solenoid coils that have a DIN interface.

IR Adapter and Cable

DIN Plug mount Amplifier with Integral Cable

991-700 HHP

Figure 4.
DIN plug mount amplifier ready for set-up.

Figure 4 shows a typical plug mount amplifier and HHP combination ready for set-up programming.
The same HHP or PC based software may be used to set-up either the embedded or plug mount amplifiers.

Both the embedded and plug mount amplifier types meet or exceed CE requirements for electro-magnetic interference (EMI) resistance.

The remainder of this Tech Tip will discuss wiring, amplifier options, operating instructions for amplifiers, HHP, software package, common system design (and operator) errors, plus the design theory behind the proportional amplifier.

3. Wiring Diagrams

The first step of the installation process is wiring the mating connector and connecting it to the customer's machine electrical system. There are three basic wiring diagrams and explanation that follow:

1. Embedded amplifier with Deutsch connector (Figure 5)
2. Embedded amplifier with DIN connector (Figure 6)
3. Plug mount amplifiers (Figure 8)

DT04-6P Connector
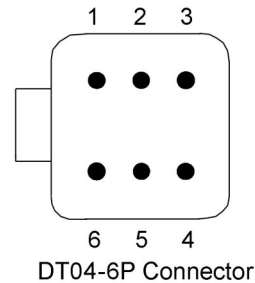
Terminal	Function	Wire Color if using 991-706-*** Mating Cable
1	+V Supply	Brown
2	Command Input	Black
3	-V Supply (common)	Blue
4	=5 V reference	Red
5	Command common	Green/yellow
6	Enable	White
-	Shield Drain	Bare

Figure 5.
Embedded Deutsch connector face
and pin out
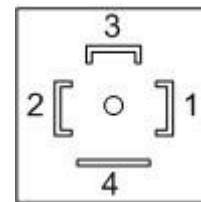
ISO/DIN 4360, Form A Connector

Terminal	Function
1	-V Supply (common)
2	+V Supply
3	Command Input
4	**Option B**- command common **Option C**- +5V reference **Option D**- enable

Figure 6.
Embedded DIN plug face and pin out

If in doubt, check the mating connector. Nearly all manufacturers mold the terminal numbers adjacent to the terminal as shown in Figure 7.

Figure 7.
Terminal identified on mating connectors.

DIN plug mount amplifiers, (C1V and C2A) have a 10 foot (3 m) cable permanently attached to the amplifier. The individual conductors should be connected to the machine control system as shown in Figure 8. *(Information is provided for service only. Plug-on amplifiers are no longer sold by Sun Hydraulics)*

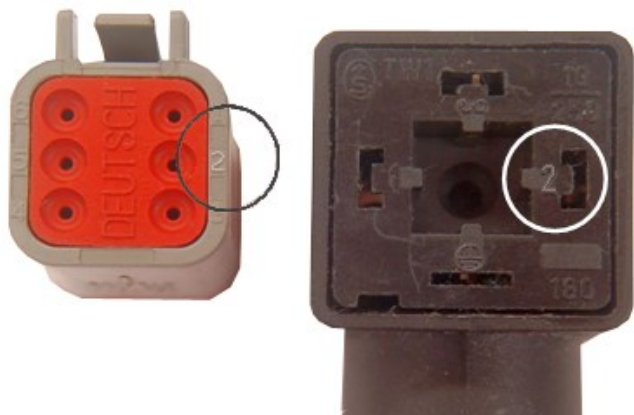| Wire	Function
BROWN	+V Supply
BLUE	Supply Common
BLACK	Command Input
WHITE	Enable Input
RED	+5 V Reference
GRN/YEL	Connector ground
Bare	Shield drain

Figure 8.
DIN plug mount wire color/function

A typical wiring diagram for all amplifiers is shown in Figure 9. Each amplifier ships with a data sheet. Please consult the applicable data sheet for the appropriate wiring diagram. While the input voltage is shown as a range from 9-28 VDC, the supply voltage should be at least equal to the coil voltage. In addition to the over voltage protection built into the amplifiers, the user should install a fuse on the input supply of power. The recommended maximum rating is 2 amps. *The use of a 2 amp (maximum) fuse is extremely important.* Please Note: All electrical wiring should be performed by qualified personnel in accordance with local electrical codes.
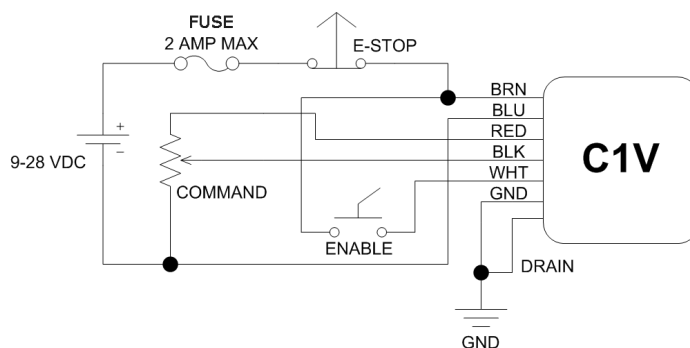
Figure 9.
Sample wiring diagram for DIN plug mount amplifiers.

Emergency Stop:

The circuit drawing shows where an emergency stop can be fitted if required. Care must be taken when both designing emergency shut down processes/circuits and selecting the hydraulic valves to be controlled by the amplifier. Incorrect valve selection can cause the loss of hydraulic machine control when the emergency stop function is activated.

Current Command:

With current command amplifiers, an external source for the 0-20 mA must be provided. Commonly, this comes from a PLC.

Voltage Command:

With voltage command amplifiers, the +5 v reference can be used as a source for a minimum 5 kΩ potentiometer. (The wiper of the potentiometer is connected to the analog input of the amplifier, as shown in the wiring diagram.) This scenario forms a very simple control system, and is commonly used in resistive style joy sticks. *(However, approximately 50% of the available control resolution of the amplifier is lost with this type of control system.)*

With 12 v supply systems, an alternative approach is to connect the input of the potentiometer directly to the 12 v supply. Although the input will exceed the 10 v maximum value when the potentiometer is adjusted to minimum resistance, the amplifier treats any command voltage above 10 v as 10 v. This approach is not as beneficial with 24 volt systems as the loss of command resolution, compared to the +5 v reference, is greater than 50%.

Enable:

Both Figure 8 and the wiring diagram in Figure 9 show a "WHITE" enable input. This option is user programmable, and is used to select a mode of operation where an enable switch is required. The enable input is an analog input with a voltage requirement between 9-28 VDC. As the wiring diagram shows, the easiest option is to install a switch after tapping into the supply voltage. Users that are commanding the amplifier with a PLC would need to install auxiliary contacts or a relay function on the PLC.

Shielding:

The cable attached to the plug mount amplifier has both a foil and braid shield, in order to achieve the highest electromagnetic immunity. The shield drain and the bare conductor should be connected to earth ground to ensure the most effective EMI protection. (Earth ground is typically the metal frame of the machine or the power supply safety ground.)

Ramping Amplifier:

Ramping amplifiers fall into the category of specialty electronics. They are an economical choice compared to a full function proportional amplifier if the proportional valve will always be operated at one of two operating points and a controlled ramp time is needed when switching between the two points. As the wiring diagram in Figure 10 shows, three connections are required in order to make the amplifier power up and initiate ramping. A voltage between 9 and 28 VDC at the analog input terminal is required to initiate the ramp-up. Removing the analog voltage will cause the ramp-down to initiate.
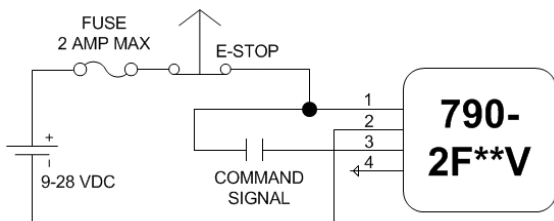
Figure 10.
Wiring diagram for ramping amplifier, 790-2F**V.

The ramping amplifier control diagram in Figure 11 shows a plot of time compared to current on the coil. Caution: Removing supply power will cause the amplifier to shut down and the valve to shift in an uncontrolled manner to the de-energized state.

Using a ramping amplifier on a switching solenoid valve is not recommended since the operation of the valve could be compromised by slowing its shifting function.
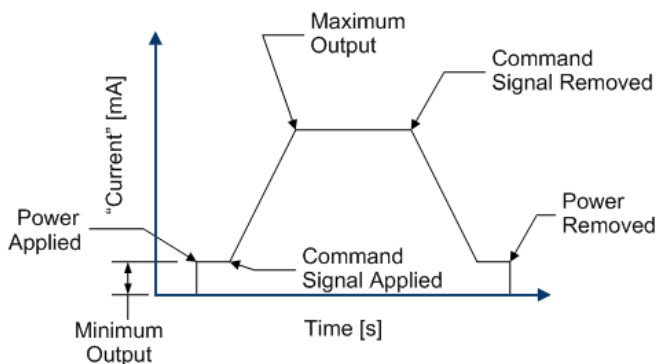
Figure 11.
Control diagram for ramping amplifier.

Power Saver:

Figure 12 shows a wiring diagram for a power saver. Refer to the wiring diagram for the specific model. When power is applied to the power saver, a shift current is applied for the programmed time. After the shift time has elapsed, the power saver reduces the current to the hold current level. The reduction in current to the coil saves power but must be high enough to ensure that the valve fully shifts. The hold current value should be chosen carefully as excessive current causes heat, which can in turn damage the coil.
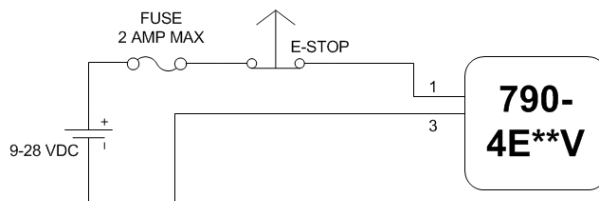
Figure 12.
Wiring diagram for power saver 790-4E**V.

Recommended maximum holding current values for 12 and 24 volt coils are the same as those recommended maximum current for the coils used on proportional valves. Figure 13 shows a control diagram of this operation and a plot comparing time vs. current to the coil.
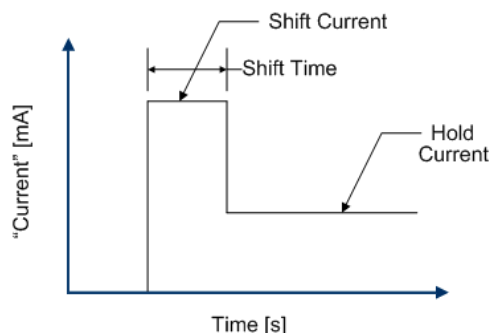
Figure 13.
Control diagram for a power saver.

When tuning, the shift and hold current settings, plus the shift time, must be chosen with care. The start current represents the shift current applied to the solenoid coil. The start current is variable and adjusts in 0.02 A increments. For optimum coil life, the *START CURRENT* and *START TIME* should be minimized to values necessary to fully shift the valve. High *START CURRENT* used with a long *START TIME* will reduce coil life. The *HOLD CURRENT* represents the reduced current applied to the coil to hold the valve in the shifted position. *HOLD CURRENT* is a variable and adjusts in 0.02 A increments. The maximum recommended value is 590 mA with 24 volts, and 1150 mA with 12 volts. Maximum *HOLD CURRENT* should fall below the curve in the shaded region in order to achieve optimum coil life (see Figure 14). The curve represents a temperature stabilized power level of 14 watts.
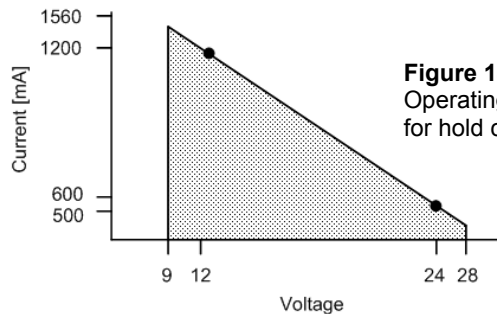
Figure 14.
Operating envelope for hold current.

The above graph also shows the recommended maximum hold current for the extremes of the 9-28 volt range of a functioning amplifier. Exceeding these recommendations could dramatically shorten coil life. The electronics in the amplifier have a self-protect feature that will turn off the microprocessor if the voltage falls below 9 VDC or exceeds 28 VDC.

4.   Hand Held Programmer Operation

Operation of Sun's hand held programmer (HHP) requires an IR cable adapter for the amplifier to be configured. The 9 pin serial connector of the cable adapter must first be plugged into the programmer. Connect the other end of the cable adapter to the amplifier. Press the yellow power button on the HHP to turn it on. The programmer can be connected or disconnected while power is supplied to the amplifier, but the amplifier must be powered on to make changes to its configuration. When the programmer powers up, it will display a title message as shown in Figure 15.

Title Screen

Low Battery Indicator
(1 of 3 segments visible)
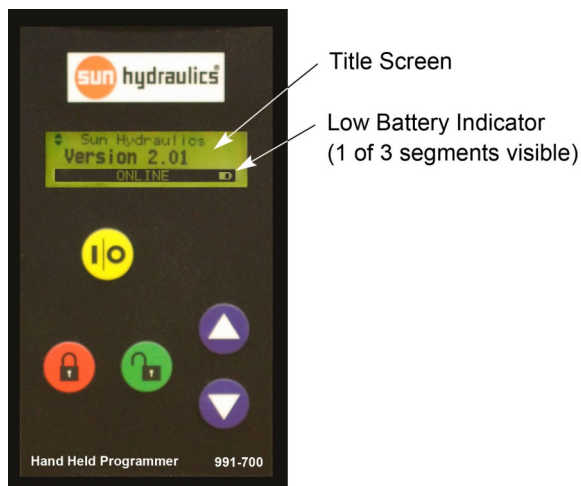
Figure 15.
Hand held Programmer 991-700.

All functions of the programmer are controlled with the following buttons: Power, Lock, Unlock, Adjust Up, and Adjust down. The specific functions of the buttons are as follows:

Power (Yellow I|O)
Turns the Programmer on and off. Briefly pressing the button when off will turn the unit on. Pressing and holding the button when power is on will turn the pro-grammer off.

Lock (Red Padlock)
Locks the current parameter setting. When locked, Adjust Up and Adjust Down control movement through the parameter list, but no settings can be changed.

Unlock (Green Open Padlock)
Unlocks the current parameter setting. When un-locked, Adjust Up and Adjust Down can change the current parameter value. A short cut key *(to avoid scrolling through available parameters for minimum and maximum inputs and outputs)* is to select the unlock button a second time when the parameter value being monitored matches the desired value.

Adjust Up (Blue with White Up Arrow)
Adjust Up will move up through a parameter list if the control is locked. If the control is unlocked, Adjust Up will increase the value of the current parameter. After pressing the first time, if the button is held depressed, the values will scroll without having to continuously press-release-press the button.

Adjust Down (Blue with White Down Arrow)
Adjust Down will move down through a parameter list if the control is locked. If the control is unlocked, Adjust Down will decrease the value of the current parameter.

4.1.   HHP Settings

The display contrast is factory set for optimum performance at room temperature. Operation at an unusually high or low temperature may require contrast adjustment. It can be adjusted in a similar fashion to the adjustment of the amplifier parame-ters.

* To enter the HHP setup area, press the lock button four times, without pressing other keys.
* The display will return to the title message which was shown when power was first supplied.
* The Up and Down arrow buttons can now be used to view and change the following HHP setting:
    - The display contrast can be adjusted to any value from 1 to 63, with 1 being lightest and 63 being darkest. The default value is 22.

CAUTION! - Setting the Contrast too high or too low can make the display unreadable.

Backlight (Version 2.0 and newer):

The display can also be adjusted for backlight brightness, to any value from 1 to 63 with 1 being the lowest setting and 63 being the brightest. The default setting is 20. Adjusting backlight brightness may prove useful in low lighting conditions.

On-board Memory (Version 2.0 and newer):

* At the read or write prompt, press the green Unlock key to change the parameter setting.
* Use either the Adjust Up or Down keys to select read or write.
* Read copies the amplifier settings onto the Hand Held Programmer's on board memory.
* Write transfers a copy of the parameters stored in the on board memory to the amplifier.
* Pressing the red Lock button completes the read or write operation.
* It is not possible to view the parameters stored in the on board memory without transferring them to an amplifier.
* It is only possible to store the parameters for one setup.

Low Battery Warning:

- Low battery warning value is 6.5 V. *(This value is not adjustable.)*
- When the battery level begins to deteriorate, an icon shows on the LCD screen.
- The fuller the icon becomes, the lower the battery level is becoming.
- As the battery level deteriorates, erratic operation might be experienced.
- For reliable operation, do not wait until the icon is full before replacing the battery.

Exiting the HHP settings area and returning to the Amplifier parameters:

- Toggle through to the parameter that reads "EXIT HHP SETUP?"
- Press the Unlock key and then the Up or Down button to change to 'Yes'.
- When the Lock button is pressed, the HHP will return to the Amplifier settings.

5. Selectable Amplifier Parameters

Modes

There are six modes of operation for plug mount and amplifiers and embedded amplifiers with the Deutsch interface. Because of the constraint of only four pins on the DIN style embedded amplifiers, a selection of three options, "B", "C", or "D", must be made by the user. (See Figure 6.)

1. Output proportional to input with Enable not used (default).
2. Output inversely proportional to input with Enable not used.
3. Output proportional to input with Enable.
4. Output inversely proportional to input with Enable.
5. Two speed where Enable provides output at the level set in Minimum Output and Command provides output at the level set in Maximum Output.
6. Two speed inverse where Enable provides output at the level set in Maximum Output and Command provides output at the level set in Minimum Output.

- Modes 1 and 3 are the most commonly used for general applications of proportional valves. With the amplifier in mode 1, increasing the command results in increasing output, e.g. more electrical current to the coil. Mode 3 functions the same way except there must be an enable signal.
- Modes 2 and 4 are inverse modes of operation. These modes of operation work inverted from modes 1 and 3. With minimum command, the output will be at the maximum. As the command value increases, the output will decrease proportionally. The difference between mode 2 and 4 is that mode 4 requires the enable signal.
- Modes 5 and 6 are two speed or two pressure modes of operation. A wiring diagram is shown in Figure 16. In mode 5, when the enable switch is closed, the amplifier will output the minimum programmed output current. This would effectively be a low speed or pressure. When the fast switch is closed, the amplifier outputs the maximum programmed current, resulting in either high speed or high pressure, depending upon the proportional valve being controlled. Mode 6 functions as the inverse of mode 5. When the

enable switch is closed, the amplifier will output the maximum current. Once the fast (now slow) switch on the black (analog input) is closed, the amplifier will reduce the output current to the minimum programmed value.
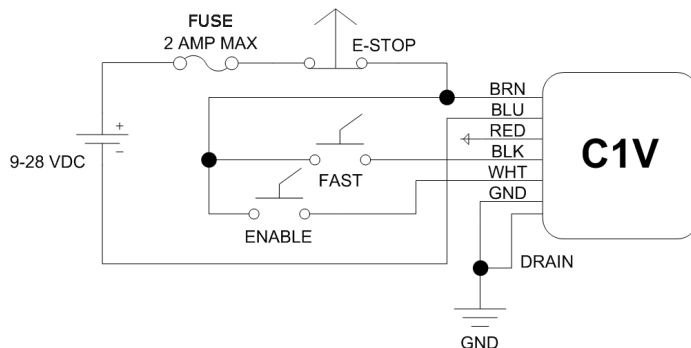
Figure 16.
Two-speed/high-low schematic.
(Information is provided for service only. Plug-on amplifiers are no longer sold by Sun Hydraulics.)

Default Parameter Values

The default parameter values that are used at Sun Hydraulics to produce the performance plots of the proportional valves advertised on the Sun web site and in catalogues, are shown in Figure 17.

- The recommended dither (PWM) frequency for Sun Hydraulics proportional valves is 140 Hz. This parameter is user adjustable, either up or down, and is often application dependent, including whether the proportional valve is piloting a larger main stage valve.
- Ramp times are the last two user adjustable parameters. The default value for both ramp up and ramp down is 0.0s. and they are independently adjustable. *(While the default values are 0.0s, many applications would benefit from a small ramp of 0.5s.)*

Ramp Times Defined:

The ramp time parameter is based on ramping from minimum to maximum command. If the step command value(s) are not from minimum to maximum, the actual ramp time will change accordingly and be different from the set parameter. For example: With a 10 s ramp specified, the actual ramp time observed with the hydraulic proportional valve will be 10 s if the command value steps from 0 v to 10 v. If the command value only steps from 0 v to 5 v, the actual hydraulic ramp time observed would be 5 s.

6. Amplifier Tuning

In order to tune the user adjustable parameters of Sun Hydraulics proportional valve amplifiers, an infrared adapter must be installed and connected either to a Hand Held Programmer (HHP) or a PC running the Sun Hydraulics Amplifier Set-Up software.

The hand held programmer is the preferred method for communication with the proportional amplifiers. USB adapters and software are offered as a convenience, but there are many uncontrollable issues that make this a less robust method of communication.

Parameter	Default Valve
Mode of Operation	1 (See description below)
Minimum Input	0.2 v for voltage command 4 mA for current command
Maximum Input	10.0 v for voltage command 20 mA for current command
Minimum Output	5 mA
Maximum Output	590 mA for 600 mA amplifiers 1150 mA for 1200 mA amplifiers
Dither Frequency	140 Hz
Ramp Up Time	0.0 s
Ramp Down Time	0.0 s

Figure 17.
Default user-selectable parameters.

Each amplifier ships from the factory with default values as shown in Figure 17. These are the same amplifier values used to control the proportional valves that generated the performance curves that are shown on Sun's website. Also, each proportional valve can be purchased with customer specified factory settings using a custom part number. With this approach, the IR adapter and HHP or the downloadable software package would not have to be purchased. However, in order to optimize the on-machine performance, regarding dead band and/or pressure or flow limiting, tuning may be necessary. *(Contact your Sun distributor regarding the custom part number option.)*

IR adapters are orientation sensitive. The photo diodes on the IR adapter must line up with the photo diodes in the amplifier. (See Figures 18 and 19) *(Care must be taken with older IR*

Top of Sun Logo

Figure 18.
Correct and incorrect orientation of the IR adapter on embedded assemblies (shown without mating connector for clarity).

Figure 19.
Correct and incorrect orientation of the IR adapter on the plug mount amplifier. *(Information is provided for service only. Plug-on amplifiers are no longer sold by Sun Hydraulics.)*

adapters not to use excessive installation force, which can cause the IR adapter to sit too low on the amplifier.)

Warning: *Before proceeding, be aware that changing parameter settings may cause sudden and unexpected machine movements. Care must be taken to prevent injury, death, or damage to equipment.*

Amplifier set up using the Hand Held Programmer (HHP) with the IR adapter:

1. IR ADAPTER
Install the IR adapter to the amplifier paying particular attention to the orientation of the Adapter—the logo side should face away from the coil and towards the embedded amplifier. The 9 pin connector must be connected to the serial port on the HHP. (See Figure 20) *(NOTE: The*

Figure 20.
HHP with IR adapter installed on an embedded assembly.

amplifier must be powered "on" in order for the IR adapter to communicate with it.)

2.   EDIT MODE

Pressing the green Unlock button when a variable parameter is displayed puts the amplifier into the edit mode.

3.   MODE

With the mode parameter displayed on the LCD screen, the desired mode setting can be selected by first pressing the green Unlock button to enter the edit mode. Use the Up or Down arrows to scroll through the list of six modes. The mode is determined by the intended use and the typical wiring diagrams shown previously. Once the correct mode has been selected, press the red Lock button to commit the change to memory and exit the edit mode.

4.   MINIMUM INPUT

Press the Down arrow to display the minimum input parameter. The first number shown on the second line is the setting value that is a variable. The second number, shown in square brackets, is the value currently present. Pressing the Unlock button enters the edit mode. The minimum input setting can be changed by pressing the Up arrow to increase the value or the Down arrow to decrease the setting. The value selected is determined by the minimum command value that is achievable. (S*electing a value lower than is actually achievable will not allow for the optimum linearity; selecting a value too high reduces the control resolution. Also, too low a value could also make the amplifier susceptible to electro-magnetic interference [EMI].)* The smallest value that may be selected is 0 Volts.

Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode. (*When working in the Inverse Mode, the monitored value displayed is the inverse value, e.g. 1 V command is displayed as 9 V.)*

5.   MAXIMUM INPUT

Press the Down arrow to display the maximum input parameter. The first number shown on the second line is the variable setting value. The second number, shown in square brackets, is the value currently present. Pressing the Unlock button allows the value to be either increased, or decreased, by pressing the Up arrow or Down arrow. The value selected is determined by the maximum command value that is achievable. *(Selecting a value that is too high will not allow for the optimum linearity; selecting a value that is too low reduces the control resolution.)* The maximum value that may be selected is 10 Volts.

Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode. (*When working in the Inverse Mode, the monitored value displayed is the inverse value, e.g. 10 V command is displayed as 0 V.)*

6.   MINIMUM OUTPUT

Press the Down arrow to display the minimum output parameter. This parameter is sometimes called dead band compensation. The first number shown on the second line of the display is the setting value while the number in square brackets is the value currently present. Pressing the Unlock button allows the value to be either increased or decreased by pressing the Up arrow or Down arrows. The value specified is determined by what value of current is needed when the MINIMUM INPUT value has been reached. A low value will increase the control resolution, but

will increase valve dead band. A higher value will reduce valve dead band (e.g. compensate for the difference between the valve components moving and not moving.)

Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode.

7.   MAXIMUM OUTPUT

Press the Down arrow to display the maximum output parameter. The first number shown on the second line is the variable setting value. The second number, shown in square brackets, is the value currently present. Pressing the Unlock button allows the value to be either increased, or decreased, by pressing the Up arrow or Down arrow. The value selected is determined by the pressure or flow required at maximum power to the solenoid coil, but should not exceed the maximum current value recommended for the coil being used. *(Exceeding the recommended value will dramatically shorten the life of the coil by producing excess heat.)* Do not forget that the recommended maximum current value for a Sun coil (produced after January 2005, having a black dichromate coil can) is 590 mA for a 24 volt coil and 1150 mA for a 12 volt coil. *(Selecting a maximum output value that is too low will limit the performance of the valve.)*
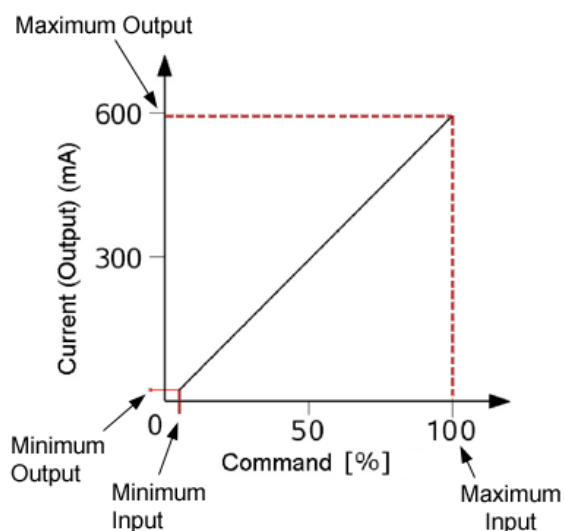
Figure 21.
Linear relationship between input values and output values.

Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode.

NOTE: Setting the minimum input and output and the maximum input and output, define two coordinates of a line as shown on the Cartesian plot shown in Figure 21.

8.   DITHER FREQUENCY (PWM)
Press the Down arrow to display the DITHER FREQ. parameter. The number shown on the second line is the dither frequency in Hertz. *(The recommended dither frequency for Sun valves is 140 Hz.)* Dither is a small amplitude oscillation at the specified frequency used to reduce friction within the valve allowing for optimal performance. The lower the frequency, the larger the amplitude of oscillation; the larger the frequency, the smaller the amplitude of oscillation. *(The amplitude is not user definable and cannot be set independently.)* Once the dither value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode. (See section 8.0 and 8.1 for more information on dither and PWM.)

9.   RAMP UP and RAMP DOWN
The ramp up and ramp down parameters are ramp rates determined by the rate input as described in steps 10 and 11. The ramp up and ramp down parameters are not required to be the same.

10. RAMP UP
Press the Down arrow to display the ramp up parameter. The number shown on the second line is the ramp time in seconds. A value between 0 and 120 seconds may be selected. Once an increase in command is detected, the amplifier will increase power to the coil in a linear manner over the ramp rate selected. Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode.

11. RAMP DOWN
Press the Down arrow to display the ramp down parameter. The number shown on the second line is the ramp time in seconds. A value between 0 and 120 seconds may be selected. Once a decrease in command is detected, the amplifier will decrease power to the coil in a linear manner over the ramp rate selected. Once the value has been selected, pressing the red Lock button commits the change to memory and exits the edit mode.

12. READY TO RUN
Setup of the amplifier is now complete. Continuing to press the down arrow allows viewing all of the monitored parameters, plus supply voltage, output current, and fault status. Access to these monitored parameters is useful if troubleshooting is required.

7.   Sun Amplifier Set-up Software (under development)

8.   Background Theory

Sun Hydraulics uses the terms dither and PWM interchangeably. The low range frequency span used by Sun amplifiers is categorized as low frequency PWM. *(However, this arrangement should not be confused with that of amplifiers that utilize high frequency PWM and superimpose low frequency dither. Neither should this be confused with PFM. When discussing the theory of operation on such devices, dither and PWM are not the same.)*

8.1.
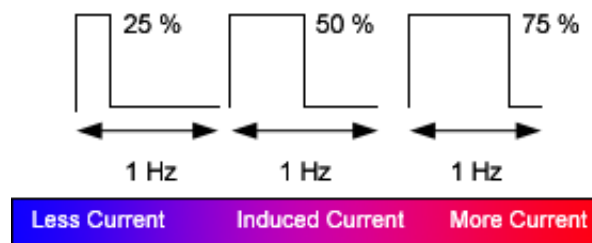
Figure 23.
PWM Duty Cycle.

Pulse Width Modulation

Pulse width modulation, or PWM, is a voltage square wave used to supply power to the solenoid coil. PWM is used because it is an efficient way of controlling DC power compared to a resistive circuit. It allows for control of large amounts of power while consuming minimal power in the process.

Changing the duty cycle (the amount of time on compared to the time off) of the voltage square wave changes the width of the pulse, but not the amplitude or the frequency. This controls the average power to the coil. This concept is shown in the simple diagram in Figure 23. The average current output for a PWM
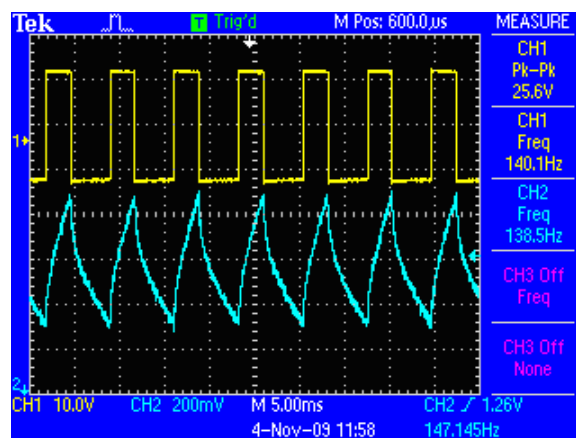
Figure 24.
Voltage square wave and current measurement
from PWM driven amplifier.

controlled system is a function of the duty cycle.

With low frequency PWM based amplifiers, changing the dither frequency also changes the PWM frequency. Sun recommends 140 Hz for the dither frequency. However, this recommendation
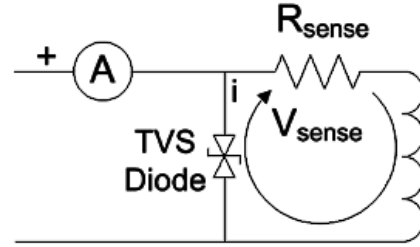
Figure 25.
Simplified schematic of current sensing.

PWM also creates the effect of superimposed dither. Dither or current ripple benefits the performance of a proportional valve by reducing the slip-stick friction that contributes to hysteresis. It also improves the valves linearity and repeatability which also can suffer because of mechanical friction in the valve.

Dither is a result of the PWM voltage square wave and the lagging current. Current lags the voltage because of the inductance in the coil solenoid system.

The effects of dither will be at a minimum near zero and maximum current. The effects of dither will be greatest at 50% duty cycle.

is based upon optimizing the valve performance on test stands. Different hydraulic actuators in different machines might require this dither frequency to be modified. Changing the frequency is done simply with the use of the IR adapter and hand held programmer or Sun's Amplifier Set-Up software.

8.2. Resolution

Proportional amplifiers can use either low frequency or high frequency PWM. Sun chose to use low frequency PWM based amplifiers because valve performance is superior to those using high frequency PWM. Low frequency based amplifiers have no dither amplitude adjustment and the dither amplitude is always at the maximum full scale supply voltage.

Too low a PWM frequency can allow a pressure ripple to develop on pressure control valves. This problem can be diagnosed by changing the dither frequency.

$$\left(\frac{3000\,psi}{1024} = 2.9\,psi \right)$$

Installation	Recommended Analog Signal	Explanation
Potential for High electrical noise	Current command	Current command is inherently more immune to electrical noise than voltage command.
Long cable runs	Current command	Cable runs greater than ~3m (10 ft) should consider the voltage drop in the cable run
Using a potentiometer or joystick	Voltage command	Voltage command is easier to apply with potentiometers and joystick applications. Cable runs should be less than 3 m.
Requires continuity checking (fault tolerance for wire break)	Current command	Current command is inherently a loop that is fault tolerant and provides easier fault diagnosis.

Figure 26.
Recommendations for analog signals.

9. Troubleshooting Flow Charts

Embedded Amplifier Troubleshooting Flowchart General Programming

Start

Cannot communicate with amplifier.

Is the amplifier Power (green) LED on?

Yes →

No ↓

Follow steps outlined in Table 1. **Is there correct voltage at the amplifier supply terminals?**

Yes →

No ↓

Correct supply problem until Power (Green) LED is on. Check power supply source, wiring, and polarity. Unit will not communicate until power LED is on.

Reverse the power supply connections. **Is the Power (Green) LED on?**

Yes ↑

No ↓

If the green LED is off with the correct power supply voltage present, the amplifier is most likely defective. Contact your local distributor for assistance.

Turn the HHP on by depressing the yellow button. **Is the display on?**

Yes →

No ↓

Check and/or change the batteries in the HHP. Normally a low battery indicator will illuminate on the display, however for extreme discharge, the display will not work. **Will the display power on?**

Yes ↑

No ↓

Verify battery voltage and connections. If OK, the HHP has malfunctioned. Contact you local distributor to obtain a replacement.

Verify the IR serial connector is securely fastened to the HHP. Verify that the IR reader marking faces the connector body. If not remove the IR reader from the amplifier rotate the IR body 180 degrees and place it back onto the amplifier. **Has communication been established?**

Yes →

No ↓

A problem exists with either the HHP, IR reader cable, or amplifier. If spares are available, change out each one individually and re-test to isolate the problem. Otherwise, contact your local distributor for further assistance.

Ready to run program amplifier.

9. Troubleshooting Flow Charts

Embedded Amplifier Troubleshooting Flowchart
Model Codes A, B, C, D, and F with Voltage Command 12 or 24 V

Start

Amplifier does not function

Is the amplifier Power (green) LED on? — Yes → Is the active (Orange) LED on? — Yes → The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.

Is the amplifier Power (green) LED on? — No → Follow steps outlined in Table 1. Is there correct voltage at the amplifier supply terminals?

Is the active (Orange) LED on? — No → Follow steps outlined in Table 2. Does the DVM measure 10 VDC at the command input terminals? — Yes → Is the active (Orange) LED on? — Yes → The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.

Does the DVM measure 10 VDC at the command input terminals? — Yes → Is the active (Orange) LED on? — No → Follow steps outlined in Table 3. Is the active (Orange) LED on?

Does the DVM measure 10 VDC at the command input terminals? — No → Follow steps outlined in Table 3. Is the active (Orange) LED on? — Yes → The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.

Follow steps outlined in Table 3. Is the active (Orange) LED on? — No → If 10 VDC is measured at the command input with the amplifier properly set and the active LED is off, the unit is most likely defective. Contact your local distributor for a replacement.

Follow steps outlined in Table 1. Is there correct voltage at the amplifier supply terminals? — Yes → Reverse the power supply connections. Is the Power (Green) LED on? — Yes → The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.

Follow steps outlined in Table 1. Is there correct voltage at the amplifier supply terminals? — No → Correct supply problem until Power (Green) LED is on. Check power supply source, wiring, and polarity. Unit will not communicate until power LED is on.

Reverse the power supply connections. Is the Power (Green) LED on? — No → If the green LED is off with the correct power supply voltage and polarity present, the amplifier is most likely defective. Contact your local distributor for assistance.

Table 1 Power Supply

- Measure supply voltage with a DVM.
- Red lead to +V supply terminal.
- Black lead to supply common terminal.
- The allowable voltage reading is:
- 10.8 to 13.2 VDC for 12 V models
- 21.6 to 26.4 VDC for 24 V models

Table 2 Voltage Command

- Input a command voltage of 10 VDC.
- If using the onboard +5V reference, verify the potentiometer is 10 Kohm or larger. Set potentiometer for +5V command voltage.
- Verifiy and set amplifier mode to 1 using HHP and IR adapter.
- Check signal connection to the command terminal.
- Connect command common to power supply common.
- Measure command voltage with a DVM.
- DVM black lead to command common/power supply common terminal.
- DVM red lead to command input terminal.

Table 3 Voltage Command

- A problem exists with the command input.
- Verify the amplifier mode is set to 1 on the HHP.
- Check the command input signal at the source first then check the signal at the amplifier.
- Verify the wiring integrity.
- Correct any problems noted.
- Verify correct polarity of the command voltage a the amplifier terminals.
- Unit will not function unless a valid command signal is present.

9. Troubleshooting Flow Charts

Embedded Amplifier Troubleshooting Flowchart
Model Codes A, B, C, D, and F with Current Command 12 or 24 V

Start

Amplifier does not function

Is the amplifier Power (green) LED on? — Yes → **Is the active (Orange) LED on?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.*

No ↓ (from "Is the amplifier Power (green) LED on?")

No ↓ (from "Is the active (Orange) LED on?") → No → *Follow steps outlined in Table 2.* **Does the DVM measure 20 mA at the command input terminals?** — Yes → **Is the active (Orange) LED on?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.*

Follow steps outlined in Table 1. **Is there correct voltage at the amplifier supply terminals?** — Yes → *Reverse the power supply connections.* **Is the Power (Green) LED on?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.*

No ↓ (from "Is the active (Orange) LED on?")

No ↓ → *Follow steps outlined in Table 3.* **Is the active (Orange) LED on?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.*

No ↓ (Table 1 branch) → *Correct supply problem until Power (Green) LED is on. Check power supply source, wiring, and polarity. Unit will not communicate until power LED is on.*

No ↓ (Reverse power supply branch) → *If the green LED is off with the correct power supply voltage and polarity present, the amplifier is most likely defective. Contact your local distributor for assistance.*

No ↓ (Table 3 branch) → *If 20 mA is measured at the command input with the amplifier properly set and the active LED is off, the unit is most likely defective. Contact your local distributor for a replacement.*
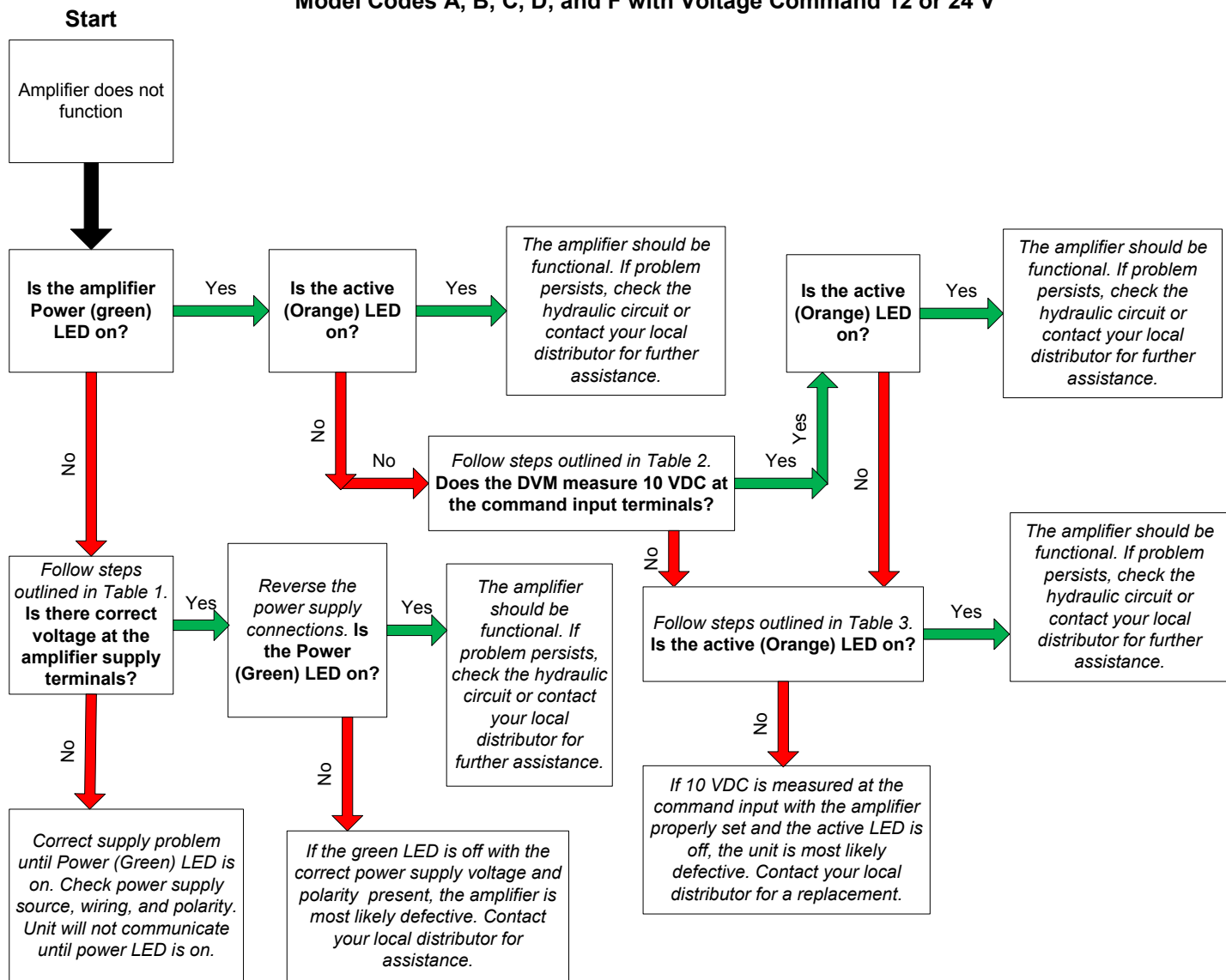

Table 1 Power Supply

- Measure supply voltage with a DVM.
- Red lead to +V supply terminal.
- Black lead to supply common terminal.
- The allowable voltage reading is:
- 10.8 to 13.2 VDC for 12 V models
- 21.6 to 26.4 VDC for 24 V models

Table 2 Current Command

- Input a command voltage of 20 mA.
- **The +5V reference signal line cannot be used as it will not supply the required current drive for the command input.**
- Verify and set amplifier to the default parameters listed on the datasheet using the HHP (hand held programmer) and IR adapter.
- Check signal connection to the command terminals.
- Measure command current with an ammeter (or a DVM set in current mode). Note that for current measurement the instrument must be placed in series with the signal line.
- Ammeter black lead to command input terminal.
- Ammeter read lead to command current source terminal.

Table 3 Current Command

- A problem exists with the command input.
- Verify the amplifier mode is set to 1 on the HHP.
- Check the command input signal at the source first then check the signal at the amplifier.
- Verify wiring integrity.
- Correct any problems noted.
- Verify correct polarity of the command voltage a the amplifier terminals.
- Unit will not function unless a valid command signal is present.

9. Troubleshooting Flow Charts

Embedded Amplifier Troubleshooting Flowchart
Model Code E Power Saver 12 or 24 V

Start

Amplifier does not function

Is the amplifier Power (green) LED on? — Yes → **Is the active (Orange) LED on?** — Yes → *Verify the amplifier is programmed with the default parameter values. The values are listed on the Model E series datasheet.* **Do the programmed parameters match the default settings?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance. Amplifier and coil functionality can be verified by observing the coil housing "warm up" following the application of power.*

No (Is the active (Orange) LED on?) → *Amplifier is most likely defective. Contact your local distributor for assistance.*

No (Do the programmed parameters match the default settings?) → *Reset the amplifier parameters using the HHP (Hand Held Programmer) and IR cable. Verify parameters using HHP after saving changes.* **Is the active (Orange) LED now on?** — Yes → (back up to functional box)

No (Is the active (Orange) LED now on?) → *The amplifier is most likely defective. Contact your local distributor for assistance.*

No (Is the amplifier Power (green) LED on?) → *Follow steps outlined in Table 1.* **Is there correct voltage at the amplifier supply terminals?** — Yes → *Reverse the power supply connections.* **Is the Power (Green) LED on?** — Yes → *The amplifier should be functional. If problem persists, check the hydraulic circuit or contact your local distributor for further assistance.*

No (Is there correct voltage at the amplifier supply terminals?) → *Correct supply problem until Power (Green) LED is on. Check power supply source, wiring, and polarity. Unit will not communicate until power LED is on.*

No (Is the Power (Green) LED on?) → *If the green LED is off with the correct power supply voltage and polarity present, the amplifier is most likely defective. Contact your local distributor for assistance.*
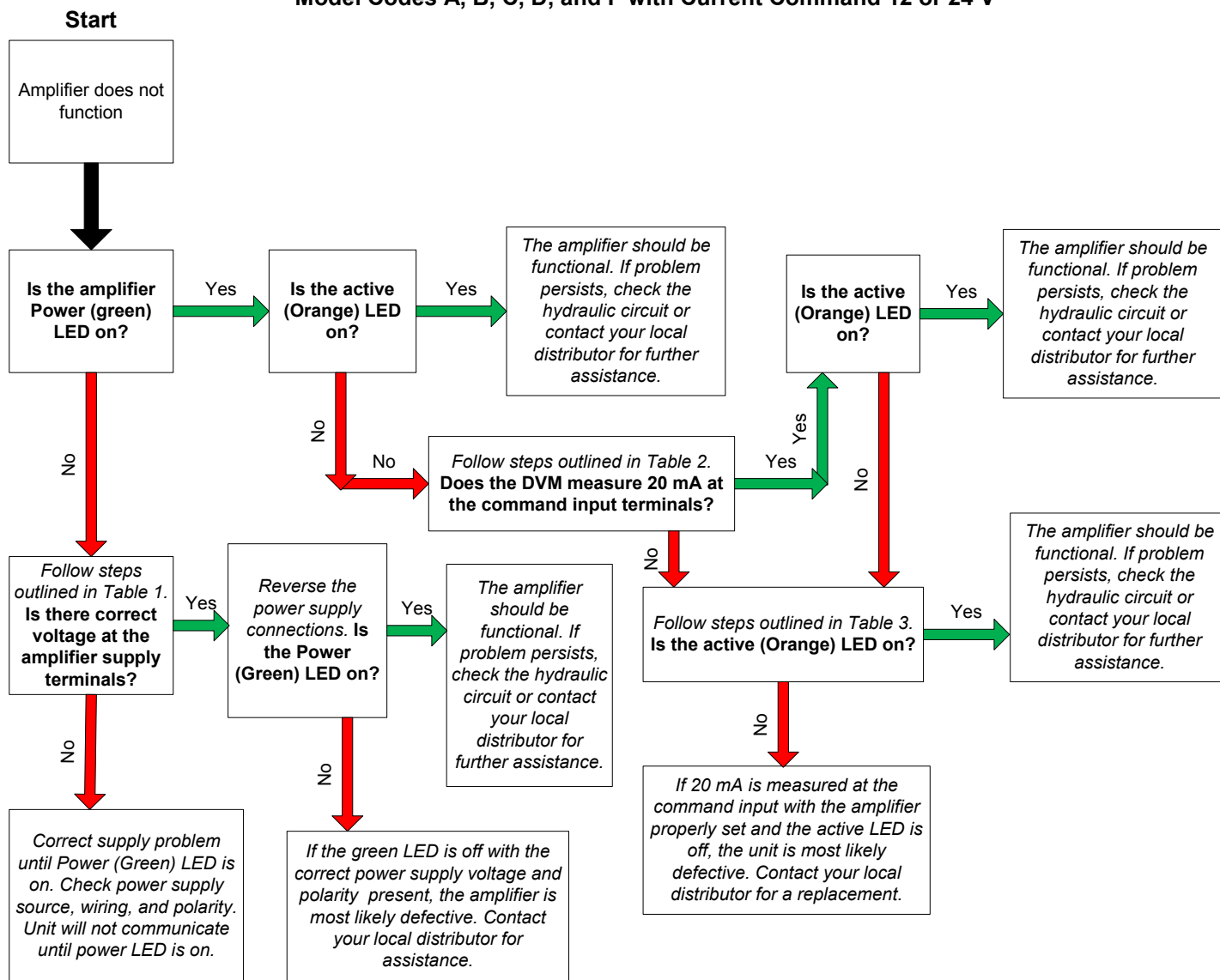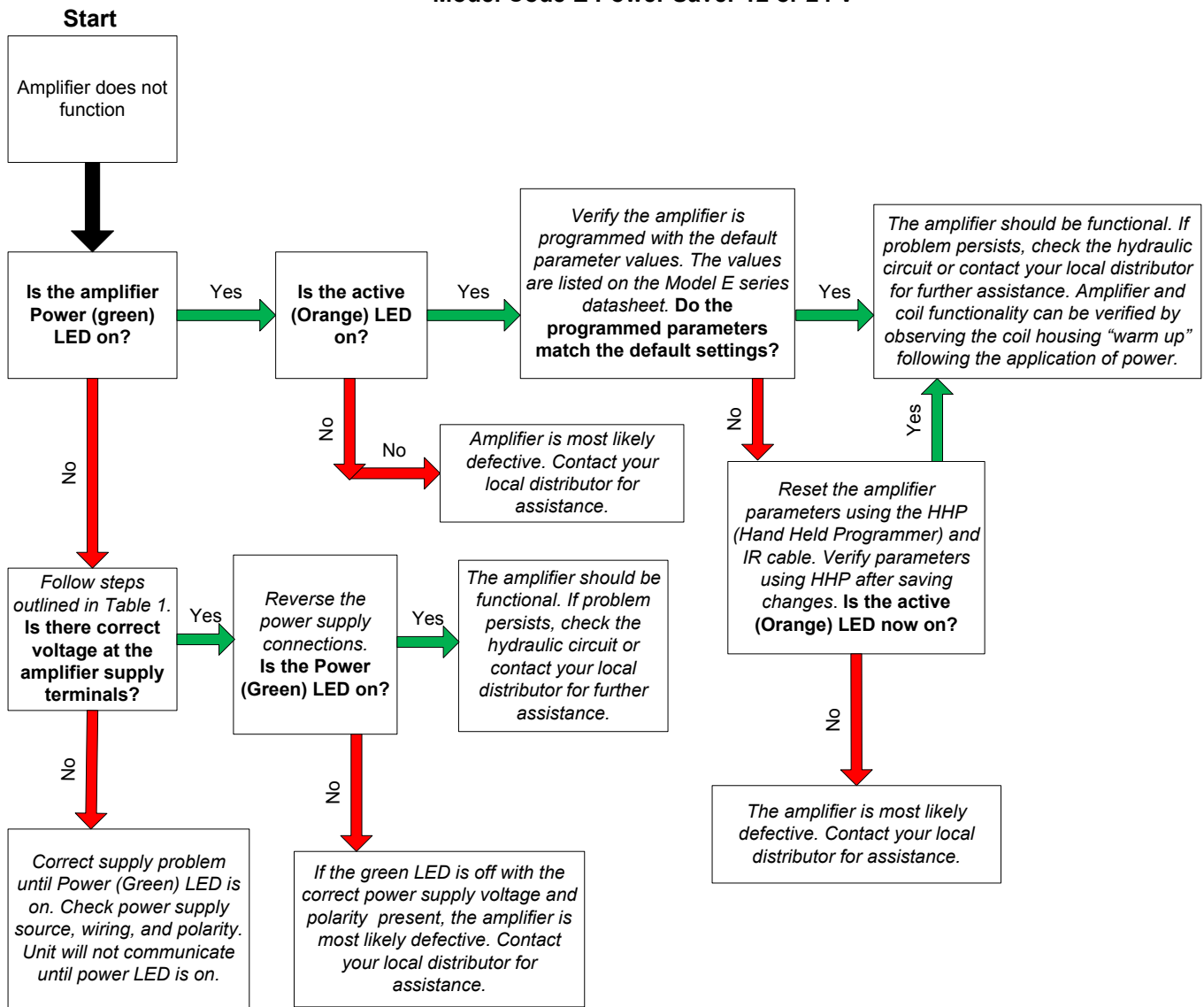
Table 1 Power Supply

- Measure supply voltage with a DVM.
- Red lead to +V supply terminal.
- Black lead to supply common terminal.
- The allowable voltage reading is:
- 10.8 to 13.2 VDC for 12 V models
- 21.6 to 26.4 VDC for 24 V models

Table 2 Voltage Command

- Input a command voltage of 10 VDC.
- If using the onboard +5V reference, verify the potentiometer is 10 Kohm or larger. Set potentiometer for +5V command voltage.

- Verify and set amplifier mode to 1 using HHP and IR adapter.
- Check signal connection to the command terminals
- Connect command common to power supply common.
- Measure command voltage with a DVM.
- DVM black lead to command common/ power supply common terminal.
- DVM red lead to command input terminal.

Table 3 Voltage Command

- A problem exists with the command input.

- Verify the amplifier mode is set to 1 on the HHP.
- Check the command input signal at the source first then check the signal at the amplifier.
- Verify wiring integrity.
- Correct any problems noted.
- Verify correct polarity of the command voltage a the amplifier terminals.
- Unit will not function unless a valid command signal is present.

10.   Amplifiers, Accessories, and Part Numbers

***Preferred Amplifiers, ***Specialty Amplifiers and Electronics

Description	Model Code	Operating Specifications
Embedded Electronics Deutsch Connector ***	790-4A24V	24V Coil, Voltage Command, All Options
	790-4A12V	12V Coil, Voltage Command, All Options
	790-4A24A	24V Coil, Current Command, All Options
	790-4A12A	12V Coil, Current Command, All Options
Embedded Electronics DIN 43650-A (ISO 4400) Connector ***	790-2B24V	24V Coil, Voltage Command, Ground Option
	790-2B12V	12V Coil, Voltage Command, Ground Option
	790-2B24A	24V Coil, Current Command, Ground Option
	790-2B12A	12V Coil, Current Command, Ground Option
Embedded Electronics DIN 43650-A (ISO 4400) Connector	790-2C24V	24V Coil, Voltage Command, +5V Reference Option
	790-2C12V	12V Coil, Voltage Command, +5V Reference Option
	790-2D24V	24V Coil, Voltage Command, Enable Signal Option
	790-2D12V	12V Coil, Voltage Command, Enable Signal Option
	790-2D24A	24V Coil, Current Command, Enable Signal Option
	790-2D12A	12V Coil, Current Command, Enable Signal Option
Embedded Electronics Deutsch Connector ***	790-4F24V	24V Coil, Voltage Command, Ramp only Option
	790-4F12V	12V Coil, Voltage Command, Ramp only Option
Embedded Electronics DIN 43650-A (ISO 4400) Connector ***	790-2F24V	24V Coil, Voltage Command, Ramp only Option
	790-2F12V	12V Coil, Voltage Command, Ramp only Option
Embedded Electronics Deutsch Connector ***	790-4E24V	24V Coil, Power Saver
	790-4E12V	12V Coil, Power Saver
Embedded Electronics DIN 43650-A (ISO 4400) Connector ***	790-2E24V	24V Coil, Power Saver
	790-2E12V	12V Coil, Power Saver

10.   Amplifiers, Accessories, and Part Numbers

Description	Model Code	Operating Specifications
Cables	991-706-003	Deutsch Mating Cable Assembly, 3m length
	991-706-006	Deutsch Mating Cable Assembly, 6m length
	991-702	IR Adapter for 790 Series Amplifiers, Serial Connector
	991-704	IR Adapter for 790 Series Amplifiers, USB Connector
HHP	991-700	Hand Held Programmer (HHP) use with Serial Connector based IR Adapter
	991-707	Sun Amplifier Set Up Software