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Warnings & Notices

WARNING:

Installation and operation of electric and high pressure systems (fluids and compressed gas) involves risk including property damage and personal injury or death.

Installers and users should be properly trained or certified and take safety precautions. This product may cause death, personal injury, or property damage if improperly used or installed.

The information in this document and other information from Enfield Technologies and its authorized representatives are intended for use by persons having technical expertise in selecting and using these products. Product owners ("you") should analyze all technical and safety requirements of your specific application, including the consequences of any possible failure, before selecting a product. This product may not be suitable for all applications, such as those acting upon people. Suitability is solely your responsibility. Because the requirements for each application may vary considerably, you are solely responsible for conducting any testing or analysis that may be required to determine the suitability of the product for your application, and to ensure that all performance, safety and warning requirements for your application are met.

Caution:

While the product is low voltage, it is an open-frame electronic component and care should be taken to prevent un-intentional contact with the product to avoid damage to person or property.

The LS-C10 is an electro-static sensitive device. Use appropriate electro-static discharge (ESD) procedures during handling and installation.

Notice:

Use and purchase of this product is subject to Enfield Technologies’ Terms and Conditions of Sale and Use. Improper installation or use voids warranty. Consult factory regarding special applications. Specifications are subject to change. Reasonable efforts have been made to provide useful and correct information in this document, but this document may contain errors and omissions, and it is subject to change.

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Overview

The LS-C10 is a simple but flexible servo controller and power amplifier designed to drive electro-mechanical actuators (e.g., voice coils, DC motors, or other electric loads) in control system configurations. It is primarily used to create proportional pneumatic systems that incorporate certain Enfield Technologies valves which use high-speed linear force motors. The LS-C10 may also be used to control or drive certain hydraulic and electric motors and systems.

Common applications include the control of position, pressure, force or flow. The LS-C10 may be configured by the user to be applied in either open-loop or closed loop systems.

By combining a proportional loop control stage with a proportional high current driver, the LS-C10 fills two primary functional roles to simplify system design as shown below. The user can configure the system numerous ways.

Role of LS-C10 in a Control System

1. Control Loop: The control loop stage determines the work effort required to resolve the difference between end-device set-point command signal and actual device monitoring feedback signal. This function is the “outer loop” using components and control signals that are often chosen by end users and are not made by Enfield Technologies. The great benefit in this approach is that users can treat the Enfield Technologies system as a “sub-system” and only send a set-point command rather than calculating detailed valve commands.

2. Valve Driver: The drive stage converts and amplifies the work effort command from the loop controller into a closed-loop valve motor drive current just as an electric motor would need a driver (amplifier) or a proportional solenoid would need a voltage duty cycle modulator. This drive stage controls the direction and magnitude of aperture in an Enfield Technologies proportional valve.
The electronics are designed to optimize the performance of Enfield Technologies LS System and M2s valves. With completely analog circuitry and a closed-loop linear amplifier, the device provides smooth “real-time” signal processing and tight control over drive current. The LS-C10 can accept a continuously changing command signal and it will change the output current (command to motor or valve) in real-time accordingly. The LS-C10 is designed to react rapidly to new command signals, but also to converge carefully on the target value to avoid overshoot.

The term “controller”, as applied to the LS-C10, is used in its classic automation definition: the LS-C10 controls the behavior of a valve or motor or whole sub-system in response to changes in certain parameters. The LS-C10 is entirely analog which has the benefit of providing fast and smooth current output with nearly infinite resolution (meaning the current output is not subject to digital sampling error and excessive processing cycle times, although it may be more susceptible to to noise, temperature, and humidity than a fully digital system). This classic use of the term “controller” should not be confused with the modern software meaning of a computer or “programmable logic controller” (PLC) used to determine a sequence of operational logic steps. In an overall system, this PLC is referred to as either a “master controller” or simply a “command signal source” (which may be as complex as a PLC or as simple as an adjustable analog voltage dial).

The LS-C10 has additional features to improve system design and performance including an auxiliary input for direct-drive or additional feedback, dither to reduce stiction, a switched output for a “system converged” signal, and an on-board single channel current-to-voltage input signal converter.

This manual primarily focuses on implementation of the LS-C10 in conjunction with Enfield Technologies proportional pneumatic valves. Occasional reference is made to implementation with motors or hydraulic valves.
Typical Applications

There are numerous applications and configurations for the LS-C10. Below are a chart of generic application descriptions and three common applications in pneumatics.

<table>
<thead>
<tr>
<th>Control Objective</th>
<th>Technology</th>
<th>Control Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Mass Flow</td>
<td>Open-Loop</td>
</tr>
<tr>
<td>Motion</td>
<td>Volumetric Flow</td>
<td>Closed-Loop</td>
</tr>
<tr>
<td>Pressure</td>
<td>Velocity (speed)</td>
<td></td>
</tr>
<tr>
<td>Force</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pneumatic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydraulic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Motor</td>
<td></td>
</tr>
</tbody>
</table>

Basic Closed-Loop Proportional Pneumatic Position Control System

Basic Closed-Loop Proportional Gas Pressure Control System

Basic Open-Loop Proportional Gas Flow Control System
Product Layout

Component Guide

The printed circuit card is provided as an open frame product, assembled into plastic housing with snap-on DIN clip for easier installation and removal using DIN rails.

The circuit card has labels which are referenced throughout this manual, often with the component code (eg: RP1) and its corresponding abbreviated text name (eg: GAIN).

TB____ = Terminal Block ("Screw Terminal"). Screw head clamp connections ("pins") for input/output wiring. The LS-C10 has only one terminal block (TB1) and these are sometimes referred to by pin number (eg: TB1-7 may be noted as Pin-7).

RP____ = Rotary Potentiometer. Screw head dial adjustments for tuning and settings.

TP____ = Test Point. Electric contacts to be used with a multimeter or an oscilloscope to monitor circuit activity for tuning and diagnostics. The screw heads on the Terminal Block (and small holes behind them) also serve as test points. All voltage measurements are generally made with reference to DC Common (TB-11 "GND").

While the product is low voltage, it is an open-frame electronic component and care should be taken to prevent unintentional contact with the product to avoid harm to both person and product. Use caution when working with wires and adjustments on the card. Many of the components are sensitive and wiring is exposed; electrically connecting some components can "short" portions of the circuitry, as can electrically connecting the heat sinks which are anodized with a thin non-conductive coating gold to diminish but not eliminate the chance of a short should they touch.
Dimensions

The circuit card may also be removed from the DIN clip housing for special application mounting using four 4-40 screws with stand-offs. Older versions of the LS-C10 may have been provided with a metal “L-bracket” for panel mounting; L-brackets may be available by special request.
## Product Specifications

<table>
<thead>
<tr>
<th>Physical</th>
<th>SI Units</th>
<th>Imperial Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (Weight)</td>
<td>0.455 kg</td>
<td>16 oz</td>
</tr>
<tr>
<td>Approximate Dimensions (L x W x H)</td>
<td>166 x 111 x 55 mm</td>
<td>6.54 x 4.37 x 2.17 in.</td>
</tr>
<tr>
<td>Materials</td>
<td>Plastics, Resins, and Electronic Components</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrical</th>
<th>Power</th>
<th>&lt;12.5W input (&lt;30W input); Max Dissipation = 10W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Requirements</td>
<td>- Power Supply Voltage</td>
<td>±12Vdc [ ±15Vdc ] * ±5%</td>
</tr>
<tr>
<td></td>
<td>- Power Supply Current</td>
<td>&lt;1.1 A [ &lt; 2.1 A ] *</td>
</tr>
<tr>
<td></td>
<td>Electronic Response Time</td>
<td>&lt; 100 µsec</td>
</tr>
<tr>
<td></td>
<td>Input Impedance</td>
<td>- Pin 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 4 &amp; 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 6</td>
</tr>
<tr>
<td></td>
<td>Electrical Connections</td>
<td>12-Pin Screw Terminal; 5mm (0.2&quot;) pitch; 16AWG max</td>
</tr>
<tr>
<td></td>
<td>Input Signal Ranges</td>
<td>- Pin 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 4 &amp; 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 6</td>
</tr>
<tr>
<td></td>
<td>Output Signal Ranges</td>
<td>- Pin 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 7 (open collector; NPN)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Pin 8 &amp; Pin 9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Environmental Protection Class</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature Range</td>
<td>0°C - 35°C</td>
<td>32°F - 95°F</td>
</tr>
<tr>
<td>Humidity</td>
<td>5% - 65% RH</td>
<td></td>
</tr>
</tbody>
</table>

*±15Vdc power supply voltage with current up to 2.1A is possible and may be required to open some valves or extend some motors fully. The higher voltage and current increases heat and may reduce product performance and life. Consult factory.*
System Requirements

The following components are minimally required to implement a system. Refer to the Product Specifications and Configuration Instructions for details.

Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Notes</th>
<th>Recommendations &amp; Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bipolar ±12V DC, 30W power supply</td>
<td>Power supply to convert AC line voltage to low voltage DC system power. Bipolar power chosen to permit real-time bipolar analog logic and regulated linear output current for bi-directional motors or valves</td>
<td>Enfield Technologies A-PS12VSB</td>
</tr>
<tr>
<td>22…28 AWG (gauge) electrical wire</td>
<td>Wire colors are suggested in the detailed wiring diagrams in the manual</td>
<td>McMaster-Carr or similar catalogs, most local hardware or electronics stores and industrial automation distributors</td>
</tr>
<tr>
<td>Valve or motor*</td>
<td>Only products approved by Enfield Technologies should be used with the LS-C10. Other products may work, but void warranty</td>
<td>Enfield Technologies LS-System valves and M2s valve (requires LS-Cable)</td>
</tr>
<tr>
<td>Valve cable*</td>
<td>--</td>
<td>Enfield Technologies LS-Cable if using an LS-System or M2s valve</td>
</tr>
<tr>
<td>DIN rail*</td>
<td>A small segment ships with the product to facilitate panel mounting without removing from the circuit card holder</td>
<td>McMaster-Carr or similar catalogs and most industrial automation distributors</td>
</tr>
<tr>
<td>Command signal source</td>
<td>Voltage command from a “master controller” such as a computer or PLC; a simple potentiometer is sufficient.</td>
<td>Enfield Technologies ASG-1 Signal Source if a simple potentiometer is needed (requires regulated excitation voltage; LS-Cable optional)</td>
</tr>
<tr>
<td>Feedback signal source*</td>
<td>If used in closed-loop mode, a voltage feedback signal from a sensor should treated for proper amplification, filtering, and scaling</td>
<td>Enfield Technologies ACT family actuators if creating a position control system</td>
</tr>
<tr>
<td>Pneumatic device*</td>
<td>If not using for flow control into the atmosphere, the system will have a &quot;device&quot; being controlled such as an actuator or pressure chamber (fixed or flexible)</td>
<td>Enfield Technologies ACT family actuators with internal position feedback sensors if a double acting air cylinder is needed (requires regulated excitation voltage and LS-Cable)</td>
</tr>
</tbody>
</table>

*Optional or dependent on system configuration

Tools

- Small flat head screw driver (preferably with a non-conductive shaft)
  - For connecting wires to terminal blocks
  - For making tuning and setting adjustments to rotary potentiometers
- Wire cutter & stripper
- Voltmeter (recommended)
  - Optional, but recommended for tuning and diagnostics
  - Multimeter recommended to also permit measurement of current and resistance
  - 2 or 3 channel oscilloscope recommended for advanced system tuning and diagnostics

Configuration

- All analog inputs are single ended and referenced to DC common
- Analog signal grounds (“DC common”) for all system electronics that interrelate with each must be tied together (made common)
- Command and feedback input signals must be coordinated when using in closed-loop mode
- Input signal must be -10…0…+10Vdc into the auxiliary input when using in open-loop mode
Theory of Operation

General

The LS-C10 has two primary functions: (1) P-Type Servo Loop Controller and (2) Driver. Within the Driver function, the system regulates current and transforms the drive signal into amplified bipolar motor current. Ancillary functions include Dither, Convergence Status, and a single channel Current-to-Voltage signal converter.

System implementation generally takes one of two forms:

1. Open-Loop (or “direct-drive”)

In open-loop configuration the Loop Controller stage is bypassed and only the drive stage of the LS-C10 is used. In this case, the input command corresponds directly to output current. When used with an Enfield Technologies valve, the intention of this configuration is for direct control of the valve aperture. Open loop configuration might be chosen for simple flow control systems where exact measurement of flow is not needed or flow sensors are too expensive for the system – in this case the overall system is truly open loop (no process control feedback). Another example is for systems where an external controller such as a PLC is closing the loop, perhaps using a complex control scheme, and only the drive stage of the LS-C10 is needed. In this case, the system is operating in open-loop mode at the LS-C10 level except for the closed-loop current control sub-stage within the drive stage. In this “direct drive” configuration, command signal must be -10…0…+10Vdc to the auxiliary input to achieve the full range of output. Direct-drive configuration allows for attenuation of the input signal and permits dither to be added to the regulated output.

2. Closed-Loop

In closed-loop configuration the LS-C10 is responsible for receiving both the set-point command and the feedback signal. In this case, only the set-point of the device being measured with a feedback signal needs to be provided, not the constantly changing valve aperture signals. However, the set-point signal itself may be continuously changing if the user wishes for the system to follow a complex ever-changing command profile. The Loop Controller stage takes care of determining what the commands to the motor or valve should be. This dramatically simplifies control system design and is a form of distributed external whereby the high speed resource consuming processing functions are shifted from a PLC or computer to the LS-C10. This also makes using a very simple set-point command signal generator possible (such as a potentiometer, function generator, or signal loop calibrator). All of the functions of the LS-C10 are available in this configuration. Command and feedback signals may be anywhere in the range of -10...0...+10Vdc so long as their ranges are coordinated (eg: 0...5Vdc corresponds to 0...100% of both command and feedback signal ranges; odd ranges are acceptable such as -2...+4Vdc). In closed-loop configuration, the auxiliary input provides an additional input to further modify the output from the Loop Controller stage. Examples: (a) “feed-forward” term, (b) additional feedback such as inverted differential chamber pressure in a positioning system, and (c) externally processed integral (I) or derivative (D) terms.
P-Type Servo Loop Controller

The servo controller consists of a proportional fixed gain difference amplifier followed by an attenuation stage\(^1\). This combination provides the dual function of adjusting control system gain while simultaneously limiting maximum current delivered to the electro-mechanical device. Thus, a single adjustment is used to control two variables to stabilize the system. This control scheme is a variation on a Proportional (“P-Type”) controller. Many users will recognize that P-Type control is one part of the more complete and complex PID control scheme (Proportional-Integral-Derivative). The P-Type controller is provided on the LS-C10 as a simple and cost effective solution that satisfies the requirements of most control systems. Other Enfield Technologies products are available to provide more flexible and accurate PID configurations (e.g.: both the LS-C41 and the C2 electronics provide PID with feed-forward).

The set-point command signal is input on TB1-1 (“CMD") and summed with the feedback signal input on TB1-2 (“FBK”). The result is amplified by a fixed gain and then attenuated by the user with the Control Loop Gain Adjustment via the RP1 (“GAIN”) adjustment screw.

“Loop Deviation”\(^2\) is the difference between the set-point command and the actual condition measured by a feedback sensor. This deviation is used to instruct the motor or valve to modulate its current or aperture so that the difference between set-point and feedback is resolved. In general for a system using a proportional valve:

- As the two signal voltages diverge, the LS-C10 increases the closed-loop current to the valve. The system is designed to open the aperture proportionally for small divergences and to fully open (“saturate”) up to a maximum setting for larger divergences.

- The system response and stability is tuned with a “gain” setting. This gain setting is generally tuned only once by the end user such that the maximum load the system is expected to experience is controlled smoothly.

- As the signals converge, the LS-C10 reduces the current to the valve causing the system to change more slowly as it approaches the set-point to minimize over-shoot. For example, an actuator will increasingly decelerate until it reaches the desired position, and in a pressure control system the rate of change of pressure will decrease as the target value grows near.

- When the desired position is reached, the valve closes.

---

\(^1\) This manual sometimes may use the more widely understood term “gain” in some instances where the functionally similar term “attenuation” is more accurate. Gain refers to the relationship between the magnitudes of an input and output signal, and it defines how sensitive the proportional response (output) is to the input. Attenuation is simply the a reduction in strength, and many of the functions on the LS-C10 have a fixed gain which is then attenuated.

\(^2\) Loop Deviation is commonly referred to as “Error” by control system designers. However, the word “error” in this context does not have the negative connotation it has in normal usage, so we use the alternate term to avoid confusion. Loop Deviation is the difference between the set-point command signal (target value) and the sensor feedback signal (actual value). Loop Deviation has a magnitude (how far away the actual value is from the target value) and a direction (or sign or polarity) which describes whether the actual value is greater or less than the target value. When the magnitude of the difference is decreasing, the system is “converging” (or “reconciling” or “resolving”), and when the magnitude is increasing the system is “diverging.”
The LS-C10 assumes that when Loop Deviation exceeds about ½ Volt in either direction, the system should respond at its maximum capability to converge (reduce the Loop Deviation to near zero). The LS-C10 provides an adjustment to this maximum saturation current output. When driving an Enfield Technologies proportional valve, this means that maximum aperture is also limited to prevent excessive flow. When Loop Deviation falls within ½ Volt of convergence on either side, then current output is directly proportional to Loop Deviation. Note that the slope of the proportional response is lower for lower gain settings.

![Current Output (Amps) as a function of Loop Deviation (Volts) and Loop Gain](image)

The accuracy of an overall system is highly dependent on several factors including friction, sensors, and characteristics of the various components (such as hysteresis, linearity, repeatability, resolution). Lower Loop Gain settings on the LS-C10 bring the system into control, but lower gains also decrease system accuracy (as is true in most control systems) because the system does not react as aggressively to commands as when gain is higher.

**Driver**

A major portion of the product application and performance is dependent on the main power output amplifier. The main drive amplifier is a trans-conductance amplifier which means that it functions as a self-contained, accurate, high bandwidth current regulator when provided with a voltage input. By coupling this topology with voice coils or DC motors, this amplifier configuration enables precise control of voice-coil force or DC motor torque. The output amplifier operates as a Class-A amplifier (high linearity, low distortion, low efficiency); because of this, there is significant thermal dissipation for most operating conditions. Care should be taken to ensure that ambient temperature limits are not exceeded and proper ventilation is provided. Note that the low efficiency should not be viewed negatively, as is the acceptable performance cost to gain the substantial performance benefits of high linearity and low distortion.

The output of the driver is a proportional bipolar motor command regulated current (–1...+1A) provided as a current loop on TB1-8 ("–Vc") and TB1-9 ("+Vc"). –Vc and +Vc are sometimes referred to as –M and +M respectively.
Dither

Dithering is a common and well understood method of reducing static friction ("stiction") in electromechanical devices. The dither waveform on the LS-C10 is implemented as a square wave current. The dither frequency is fixed at approximately 2kHz. This is within the range of human hearing, so a high pitch tone may be audible unless amplitude is lowered. The amplitude is adjustable from 0mA to approximately 300mA.

Dither amplitude is attenuated by the user via the RP2 ("SQW AMP") adjustment screw.

High dither amplitude often results in a better converging system. This is primarily due to lowering stiction as noted above. When used with valves that have a designed-in mechanical deadband to provide sealing, dither also serves to partially mask deadband when operating at and around a center-closed position.

Convergence Status

The Convergence Status signal output provides a yes/no indication of whether Loop Deviation has sufficiently converged to within a user set tolerance. This signal is useful as an input to other systems for monitoring the system or triggering other processes without monitoring and processing both command and feedback signals. There are two Control Activity LED lights associated with the Convergence Status output, and these are useful for visually monitoring basic control loop activity. The output signal and LEDs are dependent on both the Loop Deviation and a window tolerance adjustments set by the user. There are two user controlled variables that affect the output: (1) Control Loop Gain setting for system stability, and (2) Window Adjustment setting for the convergence tolerance.

The Convergence Status output signal is provided on TB1-7 ("CONV") and the Window Adjustment is made via RP4 ("ACT WDW"). The signal is an open collector which requires a resistance load to "pull-up" voltage. As shown in the diagram below, this resistor value is chosen and implemented outside the system by the end user to achieve the voltage level needed. The Convergence Activity LEDs are red and marked LD1 ("P→A") and LD2 ("P→B").

Application examples for the Convergence Status output signal:

- Trigger a relay to power a safety light or audible alarm
- Trigger a latching solenoid to release a gripper when a part is nearly in position
- Signal to a master PLC that pressure in a tank is nearly at the target value
- Signal another control system to prepare to start a second process when the LS-C10 controlled process is sufficiently complete

The Window Adjustment setting does not affect the current output to the motor or valve and thus does not alter system behavior. That is, adjusting the tolerance window does not affect the system tuning, but tuning does affect the tolerance window.

The Convergence Status signal does not indicate which side (polarity or direction) of the target valve the Loop Deviation is on, nor does it indicate the magnitude of the deviation. The objective of the output is to simply indicate whether or not the system has resolved command and feedback to within a suitable tolerance. However, the Control Activity LEDs do provide this polarity information visually.

---

3 In positioning systems, the Convergence Status concept is sometimes referred to as “at position”.

Because of the circuitry compares Loop Deviation to a tolerance window rather than the specific command set-point target value, the Convergence Status output and LEDs can be active even if the system has not completed resolving. That is, the valve or motor may still be active and operating within the tolerance window even though the signal and LEDs are reporting that the system has converged to within the tolerance window. The Convergence Status output signal and Control Activity LEDs should be interpreted only with an understanding of their meaning and limitations; they should not be relied upon for system set-up and troubleshooting and they are dependent on proper adjustment of Loop Deviation gain setting (RP1) to and the convergence window tolerance setting (RP4).

The Convergence Status is implemented using two open collector current sinking NPN transistors that are electrically arranged in an “Or” logic function. A pull-up resistor is required to produce a digital output signal for direct measurement or for use by a PLC. The sinking current and maximum voltage in the specifications should be observed for all conditions. To select a pull-up load resistor, use the following equation:

$$ R_{Pull-Up} = \frac{V_{Pull-Up}}{I_{Pin}} $$

For example, a 200 Ω resistor may be chosen to send a 10Vdc command signal with a 0.010A (10mA) load current to a computer. Another example might be triggering a 24Vdc alarm light requiring a 0.075A (75mA) current to illuminate by using a 32 Ω resistor value.

**Current Loop to Voltage Signal Converter**

A single channel converter is provided as a convenience to convert a 4…20mA current loop signal to a single-ended 0…10Vdc voltage signal (approximately). These two signal types and ranges are very common standard analog automation signals. Often, master control computers or PLCs and some sensors may only provide current loop output, particularly if long wiring runs are required to avoid signal degradation.

The 4…20mA current loop inputs are to TB1-4 (I Lo) and TB1-5 (I Hi). The “low” and “high” indications are to coordinate signal polarity. The offset is calibrated by adjusting RP5 (I→V OS). The 0…10Vdc output is on TB1-3 (I→V). The output of this converter is intended for connection to either the TB1-1 (CMD) or TB1-2 (FBK) input, or to the TB1-6 (AUX) in special cases where the motor or valve only needs to be driven in one direction or the loop modification signal is only between 0 and 10Vdc. To use the converted signal output, a wire must be connected from TB1-3 to whichever signal input is being converted (CMD, FBK, or AUX).

When the offset (RP5) is adjusted properly, the expected output voltage can be found using the following equation\(^4\):

$$ V_{Pin\_3} = (620 \times I_{Loop}) - 2.44V $$

For example, if the current (I Loop) measures 6mA (0.006A), then the expected output voltage is approximately 1.28Vdc; At the extreme ends of the range 4mA ≈ 0.04Vdc and 20mA ≈ 9.96Vdc which sufficiently functions as 0…10Vdc for most applications.

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\(^4\) Refer to the Calibration & Periodic Maintenance section near the end of this document to calibrate the current-loop signal converter.
Signal Path Diagram

The diagram below provides a high level representation of the LS-C10’s signal path. The functions are annotated with control scheme and user operation information.
Implementation Instructions

The LS-C10 can be used in many applications. Accordingly, it can be configured in many ways. These configuration instructions cover standard open-loop and closed-loop implementations as well as some advanced variations. The concepts of open-loop versus closed-loop systems, P-Type control, and a motor driver are important to implementing this or any controller-driver. If needed, please refer to the Theory of Operation section to learn about these concepts specifically in the context of the LS-C10.

WARNING:

Installation and operation of electric and high pressure systems (fluids and compressed gas) involves risk including property damage and personal injury or death.

Installers and users should be properly trained or certified and take safety precautions. This product may cause death, personal injury, or property damage if improperly used or installed.

The information in this document and other information from Enfield Technologies and its authorized representatives are intended for use by persons having technical expertise in selecting and using these products. Product owners ("you") should analyze all technical and safety requirements of your specific application, including the consequences of any possible failure, before selecting a product. This product may not be suitable for all applications, such as those acting upon people. Suitability is solely your responsibility. Because the requirements for each application may vary considerably, you are solely responsible for conducting any testing or analysis that may be required to determine the suitability of the product for your application, and to ensure that all performance, safety and warning requirements for your application are met.

Caution:

While the product is low voltage, it is an open-frame electronic component and care should be taken to prevent unintentional contact with the product to avoid damage to person or property.

The LS-C10 is an electro-static sensitive device. Use appropriate electro-static discharge (ESD) procedures during handling and installation.

Notice:

Use and purchase of this product is subject to Enfield Technologies’ Terms and Conditions of Sale and Use. Improper installation or use voids warranty. Consult factory regarding special applications. Specifications are subject to change. Reasonable efforts have been made to provide useful and correct information in this document, but this document may contain errors and omissions, and it is subject to change.
Quick Start Guide

The example wiring and plumbing diagrams can be used as Quick Start Guides for common implementations. Using these diagrams is not intended as a substitute for the full content of the product manual. Rather, they only serve to as references to provide examples to the complete user manual instructions and to facilitate a fast implementation, but not necessarily a well functioning system, for users already familiar with the product. Diagrams are available for the configurations shown in the Typical Applications section of this manual.

- Basic Closed-Loop Proportional Pneumatic Position Control System
- Basic Closed-Loop Proportional Gas Pressure Control System
- Basic Open-Loop Proportional Gas Flow Control System
Receipt Inspection & Handling

- Upon receipt, ensure the packaging is intact and the product is not damaged.
- Use care when handling the product. Avoid inadvertent connection of exposed electronics components and do not allow the anodized (gold colored) heat sinks to be electrically connected such as by having a screwdriver join them.
- Observe common electro-static discharge (ESD) procedures during handling and installation.
- Non-conductive tools are recommended, such as those with polymer or carbon-fiber type shafts.

Installation and Removal

Install the LS-C10 as follows:

- Install the LS-C10 on a DIN rail or using the four (4) mounting holes provided.
- Connect the electro-mechanical device to be driven to the target apparatus mechanically and ensure that the apparatus and area are safe for operation.
- Connect all signal and power connections to the appropriate connectors on the LS-C10.
- Connect the device drive cable to/from the LS-C10. When using an LS-Cable (or equivalent) to the LS-C10, use the following color convention:

<table>
<thead>
<tr>
<th>Wire Color</th>
<th>Connection Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>TB1-8 +Vc (M+)</td>
</tr>
<tr>
<td>Blue</td>
<td>TB1-9 -Vc (M-)</td>
</tr>
</tbody>
</table>

- Configure and tune the controller as required for specific application.

Remove the Device Controller as follows:

- Remove electrical power from the LS-C10
- Disconnect all signal connections from the C10
- Remove product from DIN rail or remove the four (4) mounting screws.
- Package the Device Controller in appropriate ESD packaging (the original packaging is preferred).

Start-Up & Shutdown

Ensure that the electromechanical system is in a state such that the system is safe, even in the event of unexpected system operation.

- Apply or remove electrical power to the LS-C10
- Ensure that the electro-mechanical device is properly connected to the LS-C10 on startup to ensure proper controller operation
- Do not attempt to change the electro-mechanical device while power is applied to the LS-C10; if changing voice coil valve (or equivalent) if connected to the LS-C10, follow these steps:
- Ensure that your application will remain safe before making any change (powering down, removing valve, powering on, etc) even in the event of unexpected valve operation
- Remove power from the LS-C10
- Disconnect the valve from the LS-C10
- Connect the new valve to the LS-C10
- Apply Power to the Device Controller.
Wiring External Connections (Terminal Block 1)

On the following pages are a table of terminal block connections and several wiring diagrams demonstrating common configurations: (1) closed-loop pneumatic positioning system, (2) closed-loop pressure control system, and (3) open loop flow control system.

Connect input and output wiring to Terminal Block 1 (TB1) using 22...28 AWG wire. Wire ends should be stripped about 3 mm (but without exposed wire showing outside the clamp) and securely clamped into terminal block positions (“pins”) with the set screw.

Most users will only need to connect 3 groups of wires to the LS-C10 (signals, valve, and power):

- **Signals:** Connect command signal input to TB1-1 and feedback signal input to TB1-2. Both of these signals should provide variable signals between -10...+10Vdc. If either signal uses a 4...20mA current loop, then see the signal conversion note below. If you use a low voltage output sensor (eg, a pressure transducer with a maximum output of 2Vdc for full scale), then you may need the LS-C30 Sensor Signal Conditioner to linearize and amplify the sensor signal prior to input to the LS-C10. Follow the directions in the Tuning section.

- **Valve or Motor:** Connect the LS-C10 to an LS System valve or M2s valve with an LS-Cable that has an M8 connector plug on one end and wires for the LS-C10 terminal block on the other end. Connect the brown wire (+) to TB1-8 and the blue wire (-) to TB1-9.

- **Power:** Connect the LS-C10 to a ±12 Volt DC Bipolar (dual) power supply (minimum 1.0A, 25W). The +12V (+) power terminal connects to TB1-10, analog ground to TB1-11, and -12V (-) to TB1-12. Enfield Technologies sells a bipolar power supply if needed, and a technical note is available describing how to create a bipolar supply using two +12V unipolar power supplies.

Other wiring connections and tips:

- **4...20mA signal conversion:** Some command controllers (PLCs and computers) and feedback sensors deliver a command in the form of a 4-20mA current loop that uses 2 wires to create a signal loop. The LS-C10 uses standard 0...10Vdc signals. Often, users can specify either 0...10Vdc or 4...20mA output signals when ordering command controllers or feedback sensors, and other times the output is selectable. Typically, an additional external signal converter must be used for signal conversion and treatment, but the LS-C10 provides an onboard buffer and signal converter for one channel. To use this conversion, connect the 4...20mA “low” signal wire to TB1-4 I Lo and the “high” signal wire to TB1-5 I Hi. The conversion output from TB1-3 must be “jumpered” (connected) to the appropriate pin (TB1-1 for command signal, TB1-2 for feedback signal, or TB1-6 for auxiliary command or feedback signal). Follow the directions in the Adjustments section.

- **Common Ground:** All components in the system should share a common ground to reduce the chance that power anomalies will create erroneous command or feedback signals.

- **Shared Power Supply:** Follow the sensor manufacturer’s instructions for powering and wiring the sensor. Many sensors use +12Vdc power and can be powered from the same supply as the LS-C10. However, Enfield Technologies recommends that if a common supply is used that it have separately regulated power supply connections for the valve and the sensor.
Terminal Block input/output connection locations:

<table>
<thead>
<tr>
<th>Function</th>
<th>Pin</th>
<th>Label</th>
<th>Description</th>
<th>Type</th>
<th>Nominal Levels</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Loop Inputs</td>
<td>TB1-1</td>
<td>[1] CMD</td>
<td>Set-Point Command</td>
<td>Input</td>
<td>-10…+10Vdc &gt;120 kΩ</td>
<td>Signal levels of command and feedback inputs should be coordinated. eg: if command is 2…8Vdc full scale, then feedback signal should also 2…8Vdc. Tune using RP1</td>
</tr>
<tr>
<td>Single Channel Current Signal to Voltage Converter</td>
<td>TB1-3</td>
<td>[3] I→V</td>
<td>Voltage output from current to voltage converter</td>
<td>Output</td>
<td>0…10Vdc</td>
<td>Calibrate offset using RP5</td>
</tr>
<tr>
<td></td>
<td>TB1-4</td>
<td>[4] Lo</td>
<td>4…20mA low side input</td>
<td>Input</td>
<td>4…20mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TB1-5</td>
<td>[5] Hi</td>
<td>4…20mA high side input</td>
<td>Input</td>
<td>62 Ω (30mA max)</td>
<td></td>
</tr>
<tr>
<td>Auxiliary Command Input</td>
<td>TB1-6</td>
<td>[6] AUX</td>
<td>Auxiliary command signal to use either as a modifier to the control loop inputs (eg: for feed-forward or the result of another processing loop) or on its own as a direct command to the drive stage (direct drive) to skip the control loop functions</td>
<td>Input</td>
<td>-10…+10Vdc &gt;10 kΩ</td>
<td>Full range of –10…+10Vdc must be used in direct drive configuration for full aperture in both directions. Tune using RP3</td>
</tr>
<tr>
<td>Convergence Status</td>
<td>TB1-7</td>
<td>[7] CONV</td>
<td>Convergence flag output using window comparator</td>
<td>Output</td>
<td>Open Collector NPN 100mA max. 36V max.</td>
<td>Indicates when Command and Feedback have converged to within the set window. Also known as an “at position” signal in positioning systems. Use Pull-Up Resistor. Use RP4 to set window range</td>
</tr>
<tr>
<td>Output to Valve or Motor*</td>
<td>TB1-8</td>
<td>[8] +Vc</td>
<td>LFM Coil (+ polarity) aka: +M</td>
<td>Output</td>
<td>~ 1…+1A up to Vss</td>
<td>Use RP2 to adjust amplitude of 2kHz dither. Higher currents possible (consult factory).</td>
</tr>
<tr>
<td></td>
<td>TB1-9</td>
<td>[9] -Vc</td>
<td>LFM Coil (- polarity) aka: -M</td>
<td>Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Supply Input (bipolar)</td>
<td>TB1-10</td>
<td>[10] +12V</td>
<td>Positive Terminal aka: +Vss</td>
<td>+12Vdc</td>
<td></td>
<td>Do not connect AGND (TB1-11) to AC ground. May be operated at ±15Vdc to drive larger valves (eg, M2 family) but requires care such as extra forced air convection cooling (fan) and limiting high current for extended periods at high ambient temperatures (consult factory).</td>
</tr>
<tr>
<td></td>
<td>TB1-11</td>
<td>[11] GND</td>
<td>Analog Ground Terminal aka: DC Common or AGnd</td>
<td>Power ± 12Vdc @ 30W</td>
<td>0Vdc</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TB1-12</td>
<td>[12] -12V</td>
<td>Negative Terminal aka: –Vss</td>
<td>(± 15Vdc possible, see note)</td>
<td>-12Vdc</td>
<td></td>
</tr>
</tbody>
</table>

*see table for LS-Cable wiring conventions in the Installation and Removal section above

To ensure that unused signal inputs do not affect the control system due to floating signals, connect these inputs to DC Common (TB1-11 or equivalent tied elsewhere in the system) and turn down (fully CCW) any associated rotary potentiometer adjustment dials.
Adjustments (Rotary Potentiometers; dials)

Overview of Adjustments

The LS-C10 has 5 rotary potentiometers as shown in the table below. These can be adjusted by tuning with a small screwdriver to change settings and tune the control system. Adjustments are analog which provides continuously variable (nearly infinite) adjustability within the setting range, but this analog circuitry also means that the exact same setting on two different LS-C10 units may not provide the exact same result.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP1</td>
<td>GAIN</td>
<td>Proportional Gain Adjustment. Range: 0.0...21.28 V/V</td>
</tr>
<tr>
<td>RP2</td>
<td>SQW AMP</td>
<td>Square Wave Amplitude (Dither) Adjustment. Range: 0...300mA</td>
</tr>
<tr>
<td>RP3</td>
<td>AUX ATT</td>
<td>Auxiliary Input Signal Attenuation. Range: 0.0...1.0 V/V</td>
</tr>
<tr>
<td>RP4</td>
<td>ACT WDW</td>
<td>Activity Window Width (Tolerance) Adjustment - Range: 0.0...5.0V</td>
</tr>
<tr>
<td>RP5</td>
<td>I → V OS</td>
<td>Current Loop Converter Offset – Range: Approx. -2.5...+2.5 V</td>
</tr>
</tbody>
</table>

These are multi-turn potentiometers that provide fine setting control by having approximately 25 revolutions across the full range of a setting, and have a slightly audible click at each end of the adjustment range. When turning an adjustment all the way down, turn counter-clockwise (CCW) at least 25 times or until you feel or hear the clicking; likewise for turning all the way up clockwise (CW).

The primary adjustments for most applications will be either RP1 and RP2 for basic closed-loop systems, or RP3 and RP2 for basic open-loop systems.

When shipped from the factory, the LS-C10 is configured as follows:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Label</th>
<th>Description</th>
<th>Initial Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP1</td>
<td>GAIN</td>
<td>Proportional Gain Adjustment</td>
<td>50%</td>
</tr>
<tr>
<td>RP2</td>
<td>SQW AMP</td>
<td>Square Wave Amplitude (Dither) Adjustment</td>
<td>100%</td>
</tr>
<tr>
<td>RP3</td>
<td>AUX ATT</td>
<td>Auxiliary Input Signal Attenuation</td>
<td>0%</td>
</tr>
<tr>
<td>RP4</td>
<td>ACT WDW</td>
<td>Activity Window Width Adjustment</td>
<td>10%</td>
</tr>
<tr>
<td>RP5</td>
<td>I → V OS</td>
<td>Current Loop Converter Offset</td>
<td>2.44V</td>
</tr>
</tbody>
</table>

**RP1 GAIN – Loop Deviation Gain Adjustment**

When closing a control loop in the LS-C10, the potentiometer dial marked RP1 GAIN functions as control system gain (actually attenuation of error signal) for the Loop Deviation which is the difference between the TB1-1 (CMD) and TB1-2 (FBK) signals. The Loop Deviation voltage is available on test point one (TP1), and it is proportional to the current the LS-C10 outputs to the motor coil to drive the valve. When RP1 is at its maximum setting (fully CW), the valve will have the best response in terms of speed and valve aperture (ie: flow path).

However, depending on the other application variables, maximum response may cause oscillation as the system continuously overshoots and aggressively attempts to correct. Tuning the gain (RP1) down with the system active and oscillating, the user can find the optimal setting where the response is the highest it can be without oscillating. In this configuration, the auxiliary path signal on Pin 6 is normally not used and there is adjustment on RP3 should be turned all the way down (fully CCW).

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5 Some LS-C10 units produced in 2006 have 11 revolution rotary potentiometers. These can be identified by the gold colored heat-sink towers which are on all units produced since 2005, but which also have small rotary potentiometers that do not fill the white rectangular component boundaries printed on the circuit card.
RP2 SQW AMP – Square Wave Dither Amplitude Adjustment

The potentiometer dial marked RP2 SQW AMP provides a 2kHz square wave dither to the valve spool. At its maximum setting (fully CW), a high pitched tone will be audible from the valve which is a high speed vibration added to the valve aperture gate (spool). The displacement of this vibration is so small and fast as to have an imperceptible effect on pressure or flow output. However, this dither helps minimize the effects of static friction in the spool and thus improves the system’s overall performance.

RP3 AUX ATT- Auxiliary Input Signal Attenuation Adjustment

The potentiometer dial marked RP3 AUX ATT functions as a gain for the TB1-6 (AUX) signal which is used for direct-drive, feed-forward, or additional command or feedback modification. Turning the potentiometer all the way down (fully CCW), will be reduced to essentially zero (as if an open circuit). Turning the potentiometer all the way up (fully CW) will maximize the input signal to its full input voltage. To adjust the valve response with respect to the auxiliary command signal, the current to the coil must be measured and RP3 adjusted with the command voltage signal going to TB1-6. When the AUX input is not used, turn RP3 all the way down (fully CCW).

RP4 ACT WDW – Convergence Status Tolerance Window Width Adjustment

The potentiometer dial marked RP4 ACT WDW is only used in a closed-loop configuration when Pin 1 is command and Pin 2 is feedback. RP4 is used to adjust the output threshold of the goal-achieved status (i.e. how close the physical condition of the system is to command). Pin 7 (Output Status) provides an optional on/off NPN (current sinking) switch for users who need to generate a signal to indicate whether the goal is within tolerance of (i.e. close enough to) the target value. The user can adjust that tolerance (and therefore, the error signal that will switch on or off Pin 7) by connecting and tuning the system using the closed-loop configuration. The user will then apply physical conditions that are at the limit of tolerable deviation from target (i.e. error between command and feedback) and turn RP4 until the red LEDs on the LS-C10 go out.

RP5 I→V OS – Current Loop to Voltage Converter Offset Adjustment

The potentiometer dial marked RP5 I→V OS is used to adjust the Zero Offset of the 4-20mA to 0-10V DC signal conversion such that 4mA equals 0Vdc. Some command controllers (PLCs and computers) and feedback sensors deliver a signal in the form of a 4-20mA current loop that uses 2 wires to create a signal loop. The LS-C10 uses standard 0…10V DC signals. Often, users can specify either 0-10V DC or 4-20mA output signals when ordering command controllers or feedback sensors, and other times the output is selectable.

To calibrate the signal conversion, use a trusted signal source such as a loop calibrator to generate a 4mA signal and then use a multimeter to test the output of TB1-3. Adjust the 4…20mA Zero Offset dial (RP5) with a small slotted screwdriver until the reading from TB1-3 is zero volts (0Vdc). Note that when RP5 is adjusted to generate 0V, output with 4mA input, an input of 20mA will generate an output of approximately 9.96Vdc which is sufficiently equal to 10Vdc for most applications.
Test Points

Test points are provided to assist in tuning and diagnostics.

- Set a voltmeter (typically a multimeter or oscilloscope) to measure DC voltage
- Most of the screw terminal block connections can be used as test points using the screw head or the small channel behind the screw.
- “Measuring from TP1 to TB1-11” means putting the meter’s positive lead on Test Point #1 and the negative lead on Terminal Block #1, Pin #11.
- TB1-11 is a frequently used in many measurements, as it is the common “analog ground” reference (aka “DC Common”).
- Measurements can also be made across any pair of test points without reference to DC Common to observe the difference between two measurements. For example, if a +/- 12Vdc power supply is used, measuring from TB1-12 to TB1-11 should read approximately -12Vdc and measuring from TB1-10 to TB1-12 should read approximately +24Vdc.
- Voltage measurements can be made across any pair of test points without harming the electronics or influencing its operation.

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Signal Description</th>
<th>Nominal Signal Range</th>
<th>Notes, Typical Use, Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>Divergence (attenuated)</td>
<td>-10…+10Vdc</td>
<td>Divergence is the control system error; the difference between set-point and feedback, after attenuation adjustment in this case. Observe post attenuation “control effort” measuring from TP1 to TB1-11. If TP6 is not used or fully counter-clockwise, TP1 should be identical in magnitude to TP4. The polarity of TP1 is inverted. So positive control error voltage gives a negative divergence voltage reading, and negative control error voltage gives a positive divergence voltage. (If CMD &gt; FBK, then TP1 &lt; 0; if CMD &lt; FBK, then TP1 &gt; 0)</td>
</tr>
<tr>
<td>TP2</td>
<td>Dither</td>
<td>-3…+3Vdc</td>
<td>Dither amplitude monitor. The amplitude of the 2kHz square wave is set via RP2 from 0…30% of full-scale ±1A drive current. So -3V…+3V on TP2 approximates -0.3…+0.3A dither.</td>
</tr>
<tr>
<td>TP3</td>
<td>Auxiliary Effort</td>
<td>-10…+10Vdc</td>
<td>Auxiliary input level after attenuation using RP3.</td>
</tr>
<tr>
<td>TP4</td>
<td>Control Effort</td>
<td>-10…+10Vdc</td>
<td>This reading is the instruction to the drive stage and represents “divergence” (aka “error”) between command and feedback, but after attenuation by the proportional gain setting (RP1) and before the amplification stage. This reading indicates the commanded direction and magnitude for valve aperture where +10V is 100% open in one direction and -10V is 100% open in the other direction. 1V reading per 0.1A output.</td>
</tr>
<tr>
<td>TB1-1</td>
<td>Command Input</td>
<td>-10…+10Vdc</td>
<td>Use to confirm that the upstream device providing the set-point command to the LS-C10 is issuing the expected signal level, or that such a signal has not degraded between the points of issue and use. Use to monitor command levels or changing command profiles. Use to confirm that the upper and lower ranges of the command signals are coordinated (eg: if 0…5V is issued by the upstream command device, then the feedback signal range should also be 0…5V)</td>
</tr>
<tr>
<td>TB1-2</td>
<td>Feedback Input</td>
<td>-10…+10Vdc</td>
<td>See the note above for TB1-1. Use TB1-2 to confirm that the feedback device is issuing the expected signal level or that the signal has not degraded. Use to monitor command levels or changing command profiles. See note above regarding coordination of command and feedback signals.</td>
</tr>
<tr>
<td>TB1-3</td>
<td>Converter Output</td>
<td>0…10Vdc</td>
<td>Use to monitor current-to-voltage converter output. Useful for adjusting output level with RP5.</td>
</tr>
<tr>
<td>TB1-6</td>
<td>Auxiliary Input</td>
<td>-10…+10Vdc</td>
<td>Observe the unmodified (pre-attenuation) auxiliary command input that modifies control effort or serves as direct-drive input</td>
</tr>
<tr>
<td>TB1-10</td>
<td>+Vss</td>
<td>+12Vdc (11.5…15.5Vdc)</td>
<td>Confirm power supply +12Vdc or +15Vdc</td>
</tr>
<tr>
<td>TB1-11</td>
<td>DC Common</td>
<td>0Vdc</td>
<td>Pin 11 on the screw terminal block TB1 is DC common and the screw head or small channel on TB1-11 can be used as a test point</td>
</tr>
<tr>
<td>TB1-12</td>
<td>-Vss</td>
<td>-12Vdc (−15.5…−11.5Vdc)</td>
<td>Confirm power supply −12Vdc or −15Vdc</td>
</tr>
</tbody>
</table>
Configuring and Tuning for Closed-Loop Control

Most users will only need to adjust one dial, Loop Gain (RP1) to tune the system. These instructions use a proportional pneumatic positioning system adjusted for high response as an example. Tuning for a pressure, force, or closed-loop mass flow control system is similar even thought the sensors and valve plumbing may be different. Turning the RP1 screwhead dial clockwise (CW, right) increases the system response and tuning counterclockwise (CCW, left) decreases the system sensitivity.

Tuning Theory

The objective of tuning is to make the system stable under its maximum expected load while seeking to achieve accuracy, minimal overshoot, minimum or maximum speed, or other performance objectives. Many system parameters influence stability including friction, command and feedback signal accuracy and quality (noise), and exogenous disturbances.

Because the LS-C10 has a P-Type design with a unique design to make it even simpler, the tuning process is much easier than PID control. The LS-C10’s control scheme is elegant in its design simplicity while yielding sufficiently high performance most system designs and decreasing design and implementation challenges.

In full PID systems, there are many established tuning theories and methods, most notably the Ziegler-Nichols method. Advanced control methods are complex because changes in tuning one term often affects the other terms, and thus the process can be recursive with several possible solutions. Academic and practical information on these theories and methods are widely available. If this type of advanced control is needed, consider alternative Enfield Technologies products such as the LS-C41 or C2.

Tuning a pneumatic system is more of an art than a science. The system probably has components from several different vendors and the components all have different dynamics characteristics such as friction, variations in signal levels, and so forth. Every application has a different set of parameters including the amount and physical orientation of the load, the speed at which the system must operate and the desired smoothness of operation, and the operating environment. Even identically configured systems have differences due to slight variations in the many parts used to make each component. Assuming that the system is required to respond rapidly, it must be tuned to operate “on the edge” of oscillation. That is, the system should be tuned to respond quickly to a command without breaking into uncontrolled oscillation or “hunting” because of signal over-saturation or target overshoot.

Basic Hands-On LS-C10 Tuning

Essentially, the system should be tested and tuned first with no load to establish a benchmark. Then the system should be operated and tested with the maximum expected load and re-tuned until it just starts to become unstable. At this point, the system should be tuned-down a little which results in the fastest achievable stable system. RP1 is an attenuator that essentially performs “gain” control adjustment as commonly understood.

When a system is unstable, it is in free oscillation such as an actuator vibrating back-and-forth uncontrollably. When this happens, turn RP1 CCW until the system is stable, however the system may need to be powered-down to prevent damage and stop the oscillation before the tuning adjustment can be effective. An under-tuned may respond sluggishly or not at all to a divergence in Control Deviation.

Make sure not to change RP2, RP3, RP4 or RP5 unless the system has a special configuration. All of these dials have been factory adjusted to the null (off) position fully counterclockwise. RP1 was set at the factory for tuning a testing device under no load. Often, this factory setting is very close to the final tuning level.
Detailed Tuning

Using the rotary potentiometer dials:

- Only make small turns of the dial, such as one-eighth (1/8) or even one-sixteenth (1/16) of a rotation, between testing actual response. The dial rotates approximately 25 times between full counterclockwise and full clockwise, but a small change on the dial can cause a big change in performance.
- By design, the dials do not have intermediate clicks or a set number of discrete positions. Rather they are analog dials that provide fully continuous adjustment so that fine detailed adjustment can be achieved whereas an indexed dial might prevent a needed half-step position. As such, these dials vary slightly from one to the next and a set number of turns cannot be prescribed for perfectly replicating the tuning of one LS-C10 to match another LS-C10.

Recommended tuning process:

First tune the system with no load to establish a properly working system and benchmark performance. Then re-tune and test with typical and maximum loads. The process is iterative. Adjust the command signal and observe the system response, repeating this process until the system exhibits its best performance. The procedure for an air cylinder positioning system is as follows:

- Reset. If resetting the system or if the system begins to behave erratically in the next step, then start by adjusting RP1 to its lowest setting by turning the dial counterclockwise (left) several revolutions.
- Test Response. Apply a target position command to the LS-C10 (a constant voltage between 0 and 10 into pin1). The cylinder may not move at all or may move very slowly to the desired position. Observe the speed and behavior of the motion.
- Gross Adjustment. Increase RP1 by turning it clockwise a half-turn. Apply another target position command and the cylinder should move to the commanded position.
- Find Maximum Performance Point. Repeat this procedure until the cylinder begins to oscillate (shake and/or vibrate) slightly at the end of the move. This oscillation should result in a very small overshoot of the desired position before a slight return to stop at the commanded position.
- Fine Adjustment. Now decrease RP1 (turn counterclockwise/left) with small dial movements (1/8th or 1/16th turns), testing the system response as in step 2 before each adjustment. Repeat this procedure until the cylinder stops in the desired location without overshoot or oscillation at the end of the move.

If the system design calls for slow response rather than high response with tuning “on the edge” of oscillation, then follow the tuning procedure above except for setting the final adjustment just below the maximum responsiveness. Examples of low tuned applications include moving heavy loads where the speed of the move is not critical or simulating human motion on a testing machine.

Configuring and Tuning for Open-Loop Control

Please contact Factory
LED Indicators

Two sets of Light Emitting Diode (LED) indicators are provided, one set to monitor control system activity and the other to monitor the power supply.

<table>
<thead>
<tr>
<th>Control Activity Indicators</th>
<th>LED</th>
<th>Color</th>
<th>Label</th>
<th>On</th>
<th>Off</th>
<th>Interpretation &amp; Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD1</td>
<td>red</td>
<td>P → A</td>
<td>Control Error outside tolerance window in positive direction</td>
<td>If LD1 and LD2 both off, then Control Error within tolerance window</td>
<td>These LEDs are a useful indication of control activity regarding motor current and control error tolerance. However, these have limitations. See the interpretation chart below for important details.</td>
<td></td>
</tr>
<tr>
<td>LD2</td>
<td>red</td>
<td>P → B</td>
<td>Control Error outside tolerance window in negative direction</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power Indicators</th>
<th>LED</th>
<th>Color</th>
<th>Label</th>
<th>On</th>
<th>Off</th>
<th>Interpretation &amp; Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD3</td>
<td>green</td>
<td>+12V</td>
<td>+12Vdc (+Vss) power supply polarity correct</td>
<td>+12Vdc (+Vss) off or polarity incorrect</td>
<td>Both LEDs will light when power polarity is connected properly. They will dim slightly if voltage is low, but a voltmeter should be used for confirming adequate power because the LEDs may still be illuminated even if voltage is below specification. It is possible to have both LEDs illuminate even though the system is in a fault condition if both +Vpp and –Vpp are connected but GND is not</td>
<td></td>
</tr>
<tr>
<td>LD4</td>
<td>green</td>
<td>-12V</td>
<td>-12Vdc (-Vss) power supply polarity correct</td>
<td>-12Vdc (-Vss) off or polarity incorrect</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Control Activity LED Additional Details (LD1 & LD2)

The control activity LEDs are a useful visual indication of motor current and control error tolerance. However, the circuitry that illuminates these LEDs is designed primarily to provide an electronic signal (output on TB1-7) that indicates whether or not the control effort is within an acceptable convergence tolerance (within a window), even if the system has not completed resolving the control error (the difference between set-point command and feedback signals). So, use of the visual LEDs for monitoring and diagnostics is subject to limitations.

If all connections are properly wired (e.g.: proper polarity) and the system is tuned properly, then these LEDs provide basic control activity information but should not necessarily be relied on for troubleshooting. The LEDs indicate which direction current is flowing, but subject to whether or not the pre-amp control effort is within a tolerance window (aka: goal window or goal flag). These LEDs are affected by user adjustments to both control error gain (RP1) and window comparator tolerance (RP4). It is possible for the motor to be active (valve open) without either of these LEDs illuminated, and it is likewise possible to illuminate either LED without the motor active (valve closed).

When one LED is on and the other is off, then both of these conditions are true: (1) current is flowing to the motor in the direction of the lit LED and (2) the pre-amp control effort is outside the tolerance window. This results in a low impedance output to TB1-7 (and thus low voltage when connected to a resistor). When both LEDs are off, current is near or around zero and pre-amp control effort is within the window – this means that, within the defined tolerance, the system has sufficiently resolved to permit an “at target” indication. When both LEDs appear to be on, they are actually flickering very fast while the system is alternating quickly between positive and negative current outside the window. The table below details each condition.

Refer to Operating Theory: Convergence Status section for more information. LD1 (P→A) and LD2 (P-
>B) indicate the polarity of the valve drive signal (for example, when the LS-C10 is connected to an Enfield Technologies LS-Series valve, positive Loop Deviation (CMD > FBK) is indicated by LD1 exists and the controller is sending positive control current to the valve in order to shift the valve ports to align port ‘P’ to port ‘A’. Conversely, LD2 indicates a negative Loop Deviation (CMD < FBK) and that the controller is attempting is sending negative current to the valve. LD1 and LD2 should never be illuminated at the same time, but they may both appear to be illuminated when the Loop Deviation is switching back-and-forth across the tolerance window faster than the LEDs can respond. The adjustment will affect when LD1 and LD2 illuminate and are extinguished.

<table>
<thead>
<tr>
<th>LD1 P→A</th>
<th>LD2 P→B</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>On</td>
<td>Off</td>
<td>Positive current output to motor (current flowing from TB1-8 to TB1-9) and control error tolerance is outside the positive side of the window. The electronic signal output on TB1-7 has low impedance and thus low voltage. For reference, if the LS-C10 is driving an LS valve in a typical positioning system configuration, then Port P (or 1) is connected to Port A (or 2) as implied by the P → A label; and simultaneously Port B (or 4) is connected to exhaust (Port 5).</td>
</tr>
<tr>
<td>Off</td>
<td>On</td>
<td>Negative current output to motor (current flowing from TB1-9 to TB1-8) and control error tolerance is outside the negative side of the window. The electronic signal output on TB1-7 has low impedance and thus low voltage. For reference, if the LS-C10 is driving an LS valve in a typical positioning system configuration, then Port P (or 1) is connected to Port B (or 4) as implied by the P → B label; and simultaneously Port A (or 2) is connected to exhaust (Port 3).</td>
</tr>
<tr>
<td>Off</td>
<td>Off</td>
<td>Current to the motor is low or nearly zero and control error is inside tolerance window. The system may still be resolving error, but for the purposes of this indicator the system is considered to have sufficiently converged. The electronic signal output on TB1-7 has high impedance and thus high voltage.</td>
</tr>
<tr>
<td>On</td>
<td>On</td>
<td>When both LEDs are illuminated, they are actually flickering on and off very quickly as the control error rapidly cycles fully across the tolerance window. If the system seems to be tuned and operating properly and this indicator seems to be in error, then the user may wish to increase the tolerance window which will not affect the control system.</td>
</tr>
</tbody>
</table>
Quick Reference Wiring Diagrams for Typical Applications

Basic Closed-Loop Proportional Pneumatic Position Control System

Legend:
- Compressed air plumbing
- Electronics wiring
- Common ground wiring

LS Cable:
8mm threaded female cable plug
For connection to 3 pin male plug on valve; pig-tail wire ends for connection to controller.

Notes:
- Caution: safety precautions for working with both electrical devices and compressed air should be observed.
- All grounds should be common.
- On the valves, ports are marked either 1-2-3-4-5 or P-B-EB-A-EA respectively.
- For optimal performance, a separately regulated power supply should be used for the sensor, but with a common ground with the rest of the system.
- To confirm proper operation (measure all voltages to ground, Pin 11): When command voltage (Pin 1) > feedback voltage (Pin 2), then voltage to valve motor on + (Pin 8, brown wire) should be > voltage on - (Pin 9, blue wire) with positive current flowing through the valve motor (from Pin 8 to Pin 9). This should cause the actuator to extend.
- Maximum currents: LS-V25 = 0.85A, LS-V15 = 0.94A, LS-V05 = 0.97A
- RP1 is the valve current adjustment. See product literature for details regarding calibration and other gain adjustments if needed.
- Configuration shown is for a typical positioning system. See product literature or contact customer service for other configurations.
Calibration & Periodic Maintenance

The LS-C10 does not require periodic factory calibration, but periodic tuning of the control system may be required due to physical changes (friction, machine and/or parts wear, etc) in the system under control and to account for any sustained changes in the operating environment's conditions such as temperature and humidity. Keep the LS-C10 free from dirt, debris, and excessive moisture.

Decommissioning & Corrective Maintenance

The device controller is not serviceable in the field. If corrective maintenance is required, contact the manufacturer for return authorization at +1 203 504 3334 (1-800-504-3334 toll free in North America) or via email at info@enfieldtech.com.
Troubleshooting

NOTE: Before proceeding any further; verify that some common problems do not exist. Test points are provided to assist in tuning and diagnostics:

- Set a voltmeter (typically a multimeter or oscilloscope) to measure DC voltage
- Most of the screw terminal block connections can be used as test points using the screw head or the small channel behind the screw.
- “Measuring from TP1 to TB1-11” means putting the meter’s positive lead on Test Point #1 and the negative lead on Terminal Block #1, Pin #11.
- TB1-11 is a frequently used in many measurements, as it is the common “analog ground” reference (aka “DC Common”).
- Measurements can also be made across any pair of test points without reference to DC Common to observe the difference between two measurements. For example, if a +/- 12Vdc power supply is used, measuring from TB1-12 to TB1-11 should read approximately -12Vdc and measuring from TB1-10 to TB1-12 should read approximately +24Vdc.
- Voltage measurements can be made across any pair of test points without harming the electronics or influencing its operation.

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Description</th>
<th>Nominal Measurement Range</th>
<th>Notes, Typical Use, Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>Control Effort</td>
<td>-10V...+10V</td>
<td>Observe post attenuation “control effort” measuring from TP1 to TB1-11. If TP6 is not used or FCCW, TP1 should be identical in magnitude to TP4 (NOTE: TP1 is inverted polarity; e.g. if CMD &gt; FBK, TP1 will be NEGATIVE)</td>
</tr>
<tr>
<td>TP2</td>
<td></td>
<td></td>
<td>Other amplitude monitor (RP2)</td>
</tr>
<tr>
<td>TP3</td>
<td></td>
<td></td>
<td>Aux input monitor (after attenuation)</td>
</tr>
<tr>
<td>TP4</td>
<td></td>
<td></td>
<td>This reading is the instruction to the drive stage and represents “divergence” (aka “error”) between command and feedback, but after attenuation by the proportional gain setting (RP1). This reading indicates the commanded direction and magnitude for valve aperture where +10V is 100% open in one direction and -10V is 100% open in the other direction.</td>
</tr>
<tr>
<td>TB1-1</td>
<td>CMD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB1-2</td>
<td>FBK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB1-6</td>
<td>Aux</td>
<td>-10V...+10V</td>
<td>Observe the auxiliary command that modifies control effort or serves as direct-drive input</td>
</tr>
<tr>
<td>TB1-10</td>
<td>-Vss</td>
<td></td>
<td>Confirm power supply -12Vdc or -15Vdc</td>
</tr>
<tr>
<td>TB1-11</td>
<td>DC Common</td>
<td></td>
<td>Pin 11 on the screw terminal block TB1 is DC common and the screw head or small channel on TB1-11 can be used as a test point</td>
</tr>
<tr>
<td>TB1-12</td>
<td>+Vss</td>
<td></td>
<td>Confirm power supply +12Vdc or +15Vdc</td>
</tr>
</tbody>
</table>
Please take notes while you are troubleshooting so that Enfield Technologies can better help you if you need assistance. A methodical approach to troubleshooting often solves problems quickly – frequently in the first step:

Confirm proper wiring
- Ensure that power is applied to the device, is of the proper polarity, and at the proper voltage. There should be power wires connected to \( +V_{ss} \) (TB1-10, typically a yellow conductor), GND (TB1-11, typically a black conductor), and \( -V_{ss} \) (TB1-12, typically a green conductor).
- Verify that all low voltage grounds (DC Common or AGND) for all components connected together (including system components outside of the LS-C10). Ensure that DC Common is not connected to ANY AC circuit wires (including Earth Ground, typically a green conductor with yellow stripe).
- Ensure that the electro-mechanical device is connected properly (if using an LS-Cable, TB1-8 should be connected to the Brown wire and TB1-9 should be connected to the Blue wire).
- Ensure that either: 
  - In Closed Loop Control Mode – Verify that both the Command Signal (CMD, TB1-1) and the Feedback Signal (FBK, TB1-2) are connected properly to both the sending device and the LS-C10.
  - In Open Loop Control Mode – Verify that the Auxiliary Input Signal (AUX, TB1-6) is connected properly to both the sending device and the LS-C10.

Basic measurements
- If you have a Digital Multi-meter (DMM or “Fluke”), there are several direct voltage measurements that can be made to assist in verifying proper LS-C10 operation and isolating potential problems.
- Use the tables and worksheets provided below to assist in troubleshooting efforts involving the LS-C10.

Basic Troubleshooting Technique
- Check Power
- Check Output
- If output good, check downstream device
- If bad, check input
- Check Input
- If input bad, check upstream device
- If input good, device is bad.
Troubleshooting Worksheet

Please collect the following basic troubleshooting information and record the Actual Results. When using a voltmeter, AGND refers to TB1-11

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Expected Result</th>
<th>Actual Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply LED Status</td>
<td>Observe</td>
<td>Green LEDs LD1 and LD2 both illuminated</td>
<td></td>
</tr>
<tr>
<td>Power Supply Voltage</td>
<td>Voltmeter</td>
<td>TB1-10 to AGND = +11.5…15.5Vdc</td>
<td>TB1-10 to AGND = +11.5…15.5Vdc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TB1-12 to AGND = -15.5…-11.5Vdc</td>
<td>TB1-12 to AGND = -15.5…-11.5Vdc</td>
</tr>
<tr>
<td>Command</td>
<td>Voltmeter</td>
<td>TB1-1 to AGND = Application Dependant</td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>Voltmeter</td>
<td>TB1-2 to AGND = Application Dependant</td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td>Voltmeter</td>
<td>TB1-6 to AGND = Application Dependant</td>
<td></td>
</tr>
<tr>
<td>Drive Voltage</td>
<td>Voltmeter</td>
<td>TB1-8 to AGND = Application Dependant</td>
<td></td>
</tr>
<tr>
<td>Drive Current</td>
<td>Voltmeter</td>
<td>TB1-9 to AGND = Application Dependant</td>
<td></td>
</tr>
</tbody>
</table>

How to Interpret Results

In Closed Loop Mode (Command applied to TB1-1 and Feedback applied to TB1-2)

If Command (CMD, TB1-1) > Feedback (FBK, TB1-2) by more than 0.5V

- Divergence Signal (TP1) should indicate a negative voltage and will depend on the RP1 setting...if RP1 is maximum, TP1 will read less than -10V (for example, -10.5V would be an acceptable measurement); if RP1 is 50%, TP1 will read approximately half of the expected value for RP1 at 100%.
- With no input to the Auxiliary Input (TB1-6), TP4 will indicate a voltage equal in magnitude but opposite in polarity to the measurement at TP1 (for example, if TP1 measures -8.0V, TP4 will measure +8.0V).
- The magnitude of the Drive Voltage (TB1-8) will indicate a value at least several volts lower than the supply voltage (for example, with an LS-Series valve, a Drive Voltage measurement of +5V or -5V is acceptable with a ±12V supply).
- The magnitude of the Drive Current (TB1-9) will indicate a value that is 1/10th the value measured at TP4 (for example, if TP4 measures -6.0V, TB1-9 will read -0.6V).

If Command (CMD, TB1-1) < Feedback (FBK, TB1-2)

- Divergence Signal (TP1) should indicate a positive voltage and will depend on the RP1 setting...if RP1 is maximum, TP1 will read greater than +10V; if RP1 is 50%, TP1 will read approximately half of the expected value for RP1 at 100%.
- With no input to the Auxiliary Input (TB1-6), TP4 will indicate a voltage equal in magnitude but opposite in polarity to the measurement at TP1 (for example, if TP1 measures 3.5V, TP4 will measure +3.5V).
- The magnitude of the Drive Voltage (TB1-8) will indicate a value at least several volts lower than the supply voltage (for example, with an M2-Series voice coil valve, a Drive Voltage measurement of +10V or -10V is acceptable with a ±15V supply).
- The magnitude of the Drive Current (TB1-9) will indicate a value that is 1/10th the value measured at TP4 (for example, if TP4 measures +8.3V, TB1-9 will read +0.83V).
In Open Loop Mode (Current Drive Command applied to TB1-6; TB1-1 and TB1-2 disconnected)

- Divergence Signal (TP1) should indicate 0Vdc; if it doesn’t, ensure that RP1 is fully counter-clockwise (FCCW).
- TP3 Measurement will depend on the RP3 setting and the input applied...if RP3 is maximum, TP3 will equal the signal at Auxiliary Input (AUX, TB1-6); if RP3 is 75%, TP3 will read approximately three-quarters of the measurement at TB1-6.
- TP4 will indicate a voltage equal to the measurement at TP3
- The magnitude of the Drive Voltage (TB1-8) will indicate a value at least several volts lower than the supply voltage (for example, with an LS-Series voice coil valve, a Drive Voltage measurement of +5V or -5V is acceptable with a ±12V supply).
- The magnitude of the Drive Current (TB1-9) will indicate a value that is 1/10th the value measured at TP4 (for example, if TP4 measures -6.0V, TB1-9 will read -0.6V).

10 Most common problems or concerns:

- Power not applied properly,
  - Power supply not regulating/maintaining acceptable supply voltage levels
  - DC Common wires not connected; improperly connected
- Improper Tuning
  - RP1 or RP3 turned fully counter-clockwise
- Inverted polarity
  - Incorrect drive current cable wiring
  - Improper mechanical system connection
- Incorrect Feedback System Connection
- Incorrect/inadequate Command or Feedback signal
- Noise
- Inverted Polarity
- Improper Wiring
- Lack of DC Common reference
<table>
<thead>
<tr>
<th>Symptom</th>
<th>Probable Causes</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Totally Unresponsive</td>
<td>Power Not Applied</td>
<td>Apply Power, check all power wiring</td>
</tr>
<tr>
<td></td>
<td>RP1 or RP3 fully counter-clockwise</td>
<td>Rotate RP1 clockwise</td>
</tr>
<tr>
<td></td>
<td>Inverted Polarity</td>
<td>Verify signal wiring and drive current wiring polarity; also verify mechanical system polarity and feedback sensor polarity</td>
</tr>
<tr>
<td></td>
<td>Signal Wiring</td>
<td>Verify all wiring is as shown in application examples and as described in the “Installation” section of this document</td>
</tr>
<tr>
<td>System Mildly Responsive or Sluggish</td>
<td>Gain too low</td>
<td>Increase RP1 setting (clockwise)</td>
</tr>
<tr>
<td></td>
<td>Power supply voltage not stable</td>
<td>Check power wiring; change power supply</td>
</tr>
<tr>
<td>System ‘Pegs’ or ‘Rails’</td>
<td>No Feedback Signal</td>
<td>Connect Feedback Signal</td>
</tr>
<tr>
<td></td>
<td>Feedback Connected Improperity</td>
<td>Verify all wiring is as shown in application examples and as described in the “Installation” section of this document</td>
</tr>
<tr>
<td>System Fails to Converge or is Inaccurate</td>
<td>Incorrect Wiring</td>
<td>Verify all wiring is as shown in application examples and as described in the “Installation” section of this document</td>
</tr>
<tr>
<td></td>
<td>Electro-mechanical device requires dither</td>
<td>Increase RP2</td>
</tr>
<tr>
<td>System Oscillates</td>
<td>Gain too high</td>
<td>Decrease RP1 setting (counter-clockwise)</td>
</tr>
<tr>
<td>System ‘Buzzes’</td>
<td>Input Signal Noise (possibly 60Hz)</td>
<td>Verify that large or high power machinery is not operating nearby. Also, verify input signal integrity by examining the signal with an oscilloscope.</td>
</tr>
<tr>
<td></td>
<td>Input Signals not connected</td>
<td>Verify all wiring is as shown in application examples and as described in the “Installation” section of this document</td>
</tr>
<tr>
<td></td>
<td>DC Common not connected</td>
<td>Verify all DC common connections are as shown in application examples and as described in the “Installation” section of this document</td>
</tr>
<tr>
<td></td>
<td>LS-C10 configured for Open-Loop AND RP1 not Fully Counter-Clockwise</td>
<td>Turn RP1 fully counter-clockwise</td>
</tr>
<tr>
<td>High Pitched Tone or Whine from Electro-mechanical device</td>
<td>Dither</td>
<td>This is an artifact of the built-in dither and is intended to keep the electro-mechanical device in constant motion. If system performance remains satisfactory, RP2 may be adjusted counter-clockwise to minimize or eliminate this sound.</td>
</tr>
</tbody>
</table>
Product Warranty

This product is covered by Enfield Technologies’ standard 1-year Limited Warranty. The terms of the Limited Warranty are subject to change. The Limited Warranty is available online at www.enfieldtech.com or by request (see contact information below).

Product Revision and Change Record

<table>
<thead>
<tr>
<th>Date</th>
<th>Identification(s)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>gold heat sinks</td>
<td>LS-C10 replaces ASP-100</td>
</tr>
</tbody>
</table>

Contact information:

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