Installation Guide
Model 23-7030

Effective: August 1, 2001
Supersedes: October 1, 1998

Servovalve
Control Amplifier
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General Description
This printed circuit card contains a complete DC servo amplifier and power supply. It is recommended for closed loop applications having single command, and similar single or dual feedback signals. In another common application, as a signal conditioner, it converts an instrumentation type signal into a valve drive current. The output circuit is a high performance current driver, with adjustable saturation current, making the 23-7030 compatible with all magnetic (non-piezo type Parker servovalves, hydraulic and pneumatic). The on board DC power supply is regulated and suitable for operation of associated loop devices, command sources and sensors.

Specifications

<table>
<thead>
<tr>
<th>Dimension</th>
<th>4.50” x 6.75” x 1.60”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rack Space Requirement</td>
<td>2 inches per axis - 3 units high</td>
</tr>
<tr>
<td>Connector Requirement</td>
<td>22 Pin .156” centers - card edge and screw terminal barriers</td>
</tr>
<tr>
<td>Power Supply Requirement</td>
<td>115 VAC 60 Hz, 16 VA at full load</td>
</tr>
<tr>
<td>Power Supply Output Regulated ±15 VDC @ 380 mA, maximum</td>
<td></td>
</tr>
<tr>
<td>Servo Control Circuit Reference schematic diagram DWG# 23-7031</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Proportional, open or closed loop control</td>
</tr>
<tr>
<td>Inputs</td>
<td>100K ohms command input resistance 2 feedback inputs at 100K ohms each 10K ohms proportional inner loop 4-20 mA inputs for command and feedback, 250Ω each.</td>
</tr>
<tr>
<td>Outputs</td>
<td>Minimum load resistance – short circuit proof ±325 mA* maximum valve drive current ±12 VDC* maximum valve drive voltage ±12 VDC from 10KΩ source error output reference</td>
</tr>
<tr>
<td>Gain</td>
<td>Range: 40:1 mA/Volt – load dependent</td>
</tr>
<tr>
<td>Drift</td>
<td>0.1 mV per C° (referred to input temperature range +10C° to +50C°) with 100KΩ input resistance and 50 mA DC per volt setting</td>
</tr>
<tr>
<td>Dither</td>
<td>0-100% adjustable amplitude at 200 Hz</td>
</tr>
<tr>
<td>Frequency Response</td>
<td>&lt; 3 dB down at 1200 Hz within voltage saturation limits and with load inductance of &gt; 1 henry</td>
</tr>
<tr>
<td>Deadband or Hysteresis</td>
<td>None</td>
</tr>
</tbody>
</table>

* Maximum values are load dependent and not combined

Circuit Controls
Reference Drawing # 23-7030
Seven screwdriver adjustments are available. The potentiometers are directly mounted to the printed circuit card. Three set-up parameters are card face adjusted while four system variables are front card edge mounted.

Span (R2)
Adjusts the magnitude of command voltage, thereby adjusting the overall stroke, velocity, or pressure of the servo loop. The range of adjustment is zero to 100% of rated input voltage as measured at Test Point “A” (T.P.A.). This is a multi-turn potentiometer for precision circuit adjustment. The span adjustment is card edge mounted for easy access when rack mounted.

Feedback Gain (R8)
Adjusts the magnitude of feedback signals. The effect is similar to adjusting the span. The range of adjustment is zero to 200% of rated input voltage as measured at T.P.B. Factory set to same level as span signal. This is a multi-turn, card-edge access potentiometer.

Error Gain (R11)
Sets the proportional servo loop gain throughout a 40:1 range. Other ranges are available, consult factory for alternate requirements. This is a card-edge access, multi-turn potentiometer.

Offset (R21)
Provides a plus or minus offset for system nulling or for biasing the output. With standard components the bias adjustment is limited to a 20% offset of the rated output current. Factory set to zero offset, this is a multi-turn card-edge access potentiometer.

Dither Level (R17)
Adjusts the dither (200 Hz square wave) level from zero to 10% of the net output current. This is a top access, single-turn adjustment, factory set to zero.

Current Limit (R23)
Adjusts the current saturation level of the output amplifier. This adjustment is used to match the output to the rated full flow requirement of the valve. R23 may also be used to limit a servovalve’s output flow by adjusting the current output to be below the rated full flow requirement.

Signal Offset Reference (R7)
Provides adjustable output resistance of the -5V reference voltage, for use in offset of signal conditioning applications.
Circuit Description
Reference Drawing # 23-7031

Servo Control Circuit
The servo control circuit contains four operational amplifier stages. Jumper blocks J1 & J2 provide 250 ohm loads to command and/or feedback inputs for conversion of 4-20 mA signals to +1 to +5VDC signals. The command input signal (connector pin 8, terminal block J) is attenuated by the span adjustment R2, and applied to buffer amplifier A1 at pin 12. The span amplifier output can be checked at test point “A” (T.P.A.). Feedback input signals at pins 7 and/or 16 (connector blocks K and/or E) are added together, and adjusted for amplitude by “feedback gain” potentiometer R8 and inverting amplifier A1 at pin 9. The feedback amplifier output can be checked at test point “B” (T.P.B.). Diodes D1 and D2 protect the feedback amplifier from inadvertent over voltage conditions. Voltages from test points A and B are summed and multiplied by the error gain factor R11. The resulting error signal can be checked at T.P.C. Potentiometer R21 adds a DC bias to the servo error signal for fine offset adjustments to the loop. The proportional inner loop input and error signal remote output are also accessed at this point. This final signal is converted to current by amplifier A2, a high performance power operational amplifier. The current saturation of the output may be adjusted by R23, thus adapting to a variety of current/coil combinations and protecting the valve coils from over current, or limiting the flow rate of the servovalve.

Dither Generator
The dither generator is a multi vibrator circuit around 1/4 of amplifier A1. Standard components produce a 200 Hz dither signal. Other frequencies can be obtained by changing capacitor C3.

Dither level set by R17 is unaffected by loop gain changes.

Phase Compensation
Two types of phase compensation are available, both with user provided components. The first is rate compensation at feedback input 1. By adding resistor R4 and capacitor C2 as a high pass network, a form of phase lead or derivative effect can be produced. The second is a simple integrator of the error amplifier by adding capacitor C1 at the pads provided. A basic knowledge of servo analysis is useful in selecting component values, as they are individual to each application.

Signal Offset Reference (SOR) Output
Zener diode Z1 provides a stable voltage reference, while potentiometer R7 provides adjustable output impedance. The output of this circuit is available at card edge pin 17 and terminal block D. The signal can be connected to command or feedback inputs as part of various signal conditioning applications.
Input Signal Alignment

Command and Feedback

For loop closure applications the command and feedback signal types should be selected as similar types. Typically, the following table of compatible types will perform best with the standard alignment.

Current Input Signal Jumpers

The two moveable jumper blocks, J1 & J2, can connect 250Ω load resistors, R1 & R30, from the command & feedback inputs to signal common. A 4-20 mA signal will then pass through the load, returning to its source via signal common, producing a 1-5V signal at the input. Jumper J1 is for the command input, and J2 is for the #2 feedback input. The left or “I” jumper position connects the load. The right or “E” jumper position disconnects the load.

Notice: Do not connect a voltage type signal to an input with its jumper on “I”.

Connect unused feedback input terminal(s) to signal common for optimum signal.

<table>
<thead>
<tr>
<th>Command</th>
<th>Feedback</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>±10V</td>
<td>±10V</td>
<td>Factory Standard Alignment</td>
</tr>
<tr>
<td>0-10V</td>
<td>0-10V</td>
<td>Standard Alignment</td>
</tr>
<tr>
<td>±5V</td>
<td>±5V</td>
<td>Standard Alignment</td>
</tr>
<tr>
<td>0-5V</td>
<td>0-5V</td>
<td>Standard Alignment</td>
</tr>
<tr>
<td>±10V</td>
<td>±5V</td>
<td>Span or F.B. Gain adjust required</td>
</tr>
<tr>
<td>±5V</td>
<td>±10V</td>
<td>Span or F.B. Gain adjust required</td>
</tr>
<tr>
<td>0-10V</td>
<td>0-5V</td>
<td>Span or F.B. Gain adjust required</td>
</tr>
<tr>
<td>0-5V</td>
<td>0-10V</td>
<td>Span or F.B. Gain adjust required</td>
</tr>
<tr>
<td>±5V or ±10V</td>
<td>None</td>
<td>Span or F.B. Gain adjust required</td>
</tr>
<tr>
<td>4-20 mA</td>
<td>4-20 mA</td>
<td>Standard Alignment: J1 &amp; J2 to I positions</td>
</tr>
<tr>
<td>0-10V</td>
<td>None</td>
<td>J1 to E position, SOR to Auxiliary Input</td>
</tr>
<tr>
<td>4-20 mA</td>
<td>None</td>
<td>J1 to I position, SOR to Auxiliary Input</td>
</tr>
<tr>
<td>4-20 mA</td>
<td>1-5 VDC</td>
<td>J1 to I position, J2 to E position</td>
</tr>
<tr>
<td>1-5 VDC</td>
<td>4-20 mA</td>
<td>J1 to E position, J2 to I position</td>
</tr>
<tr>
<td>4-20 mA</td>
<td>±10 VDC</td>
<td>J1 to I position, J2 to E position, SOR to Auxiliary</td>
</tr>
</tbody>
</table>
Standard Span and Feedback Gain Adjustment

1. With the hydraulic supply turned off and the servovalve electrically disconnected, apply 120 VAC to terminals B and C.
2. Apply maximum feedback and command signals to the appropriate connector terminals. (non-SOR applications)
3. Measuring voltage at T.P.A., adjust Span pot R2 clockwise for maximum voltage (do not exceed ±12 VDC). Note the voltage.
4. Measure voltage at T.P.B. while adjusting F.B. Gain pot R8 to produce a T.P.B. measurement equal in magnitude, but opposite in polarity to the voltage at T.P.A.

Current Driver Adjustment

The current driver is factory calibrated to ±50 mA output. If re-calibration is required, use the following procedure.
1. Insure that the appropriate jumper wires are installed in the servovalve and that the servovalve is wired properly (see section on servovalve wiring).
2. Note mA rating on servovalve nameplate. Valves requiring over 150 mA for full flow, require changing of resistor R26 from 22 ohm to 5 ohm.
3. Set voltage at T.P.E. to 0.0V by adjusting pot R21.
4. Adjust dither signal amplitude to zero (pot R17 full CCW).
5. Connect a current meter in series with servovalve, from the amplifier output (pin 1 or terminal 0) to the amplifier return (pin 3 or terminal N).
6. Adjust current limit (R23) fully CCW (minimum output).
7. Adjust Error Gain (R11) to 50% nominal rotation.
8. With the command or feedback signal at its minimum value, adjust the other to its maximum level (simulate a large following error condition).
9. Slowly adjust Current Limit (R23) clockwise until the meter displays the mA rating of the servovalve.

Offset Adjustment (R21)

1. Set command and feedback signals to minimum values. Verify that the voltages at T.P.A. and T.P.B. are of equal value, but opposite polarity. This simulates a zero error condition (non-SOR applications).
2. Set the error gain (R11) to 50% visually.
3. Adjust R21 for zero current to servovalve.

—Warning—

Energizing a servovalve over its rated current can damage the valve!
### Servovalve Wiring

Recommended wiring for new applications is a parallel connection of the servovalve coils. Parallel wiring is preferred for two primary reasons, the frequency response of the valve is higher as a result of the reduced inductance (parallel coil law), and the unlikely event of a valve coil failing open will not result in a system failure. Using a Parker servovalve as a replacement for other makes, may require series wiring of the coils to match the valve being replaced. The Model 23-7030 control amplifier will operate other makes of servovalves effectively with series or parallel wiring. Both wiring methods will require jumper(s) to be installed at the valve end of the two conductor cable connecting the valve to the amplifier.

![Servovalve Wiring Diagram](image)

### Basics of Closed Loop Servo Control

This section is intended to provide a brief description of closed loop servo control. The following two definitions will make this easier to understand:

**Controls** - means the Hydraulic Valve Division-7000 Series Electronics which are controlling a servovalve and in turn some type of servo system.

**System** - means the machine, actuator, hydraulic motor, pressure line, fluid level or what ever it is that is being controlled through the use of a servovalve.

In a typical closed loop servo control system the intent is to control one or more system parameters very precisely. This can be the position of an arm, the velocity of a shaft, the pressure in a chamber, the force on a specimen, the flow rate of a fluid or any other possible type of system parameter or combination of multiple parameters. In any case the parameters are real world, where mechanical action is required to maintain the parameter at some predetermined level. This is the job of the controls.

To maintain a system parameter at some level, the controls need to know what the required level is. This is called the command signal. The command signal can come from a knob or dial on a control panel, be generated by a computer or some other source that is usually changing constantly. The command signal can even come from the status of some other system parameter, as in a follower circuit or master slave configuration.
Basics of Closed Loop Servo Control

(continued)

Another requirement for the controls to maintain a system parameter is the current real time status of the parameter. This is accomplished through the use of a feedback signal, proportional to the current status of the system parameter. Feedback is usually provided by some type of device, directly coupled to the system parameter under control, such as a position transducer, tachometer, pressure sensor, load cell, etc. In some cases the feedback can be calculated from some other source that is proportional to the parameter, such as the force applied by an actuator being proportional to the pressure in it. Directly reading the parameter being controlled is usually more desirable for the most accurate control.

With the command and feedback the controls can do their work. The controls have the job of comparing the feedback signal with the command signal and then outputting a signal that is proportional to the difference between the signals. This output is an error signal that must be compatible with the device used to control the system. In this case that is a servovalve. The servovalve then responds to the error signal in an attempt to correct or minimize it. This response causes the feedback to change thereby reducing the error, hence the output to the servovalve and the whole closed loop process continues, always correcting for the error between the command and feedback signals.

For the controls to compare the command and feedback, it is important that these signals be completely compatible. Adjustments on the controls allow the command and feedback signals to be individually scaled so they can be made compatible. Other circuits included with the controls allow signal formats to be changed for compatibility. The following section on command and feedback considerations shows the most common forms of compatible signals. Many others are possible.

Further information on servo systems is available in the following books:

- Electrohydraulic Servo Systems
- Hydraulic System Analysis
- Fluid Power Systems & Circuits
- Design of Electrohydraulic Systems for Industrial Motion Control

These books are available from the publishers of Hydraulics & Pneumatics Magazine, at the following web address:

www.FPWeb.com

System Considerations

This section describes many of the things that must be considered in putting together and using a servo control system. An important consideration is the choice of command and feedback signals. Other general considerations that are significant for good system performance are servovalve sizing, valve wiring, feedback coupling and other system dependant functions.

Command Feedback Sources

The 23-7000 Series Controls are analog by design, requiring analog signals for command and feedback sources. Common analog sources for command signals are potentiometers, digital to analog converters, and feedback signals from other related parameters. The type of command signal should be determined by matching it to the feedback signal, for example a 0 to +10 volt position feedback device will work best with a 0 to +10 volt command source, but with a ±10 volt command source, configuration is more complex and requires additional signal conditioning. The majority of feedback sensors available today are analog output devices. This makes them compatible with the requirements. Any device having a low level output such as a strain gauge or load cell will require additional signal conditioning, usually available from the sensor manufacturer.

Feedback devices vary greatly in accuracy and cost accordingly. Appendix B contains a short list of typical servo grade devices and vendors. A complete listing of sensors, transducers, and manufacturers is available from the publishers of Sensors Magazine at the web address below, followed by some comments on a few of the various types:

www.sensorsmag.com

Position Feedback — The three most common linear position feedback types are:

- Linear Potentiometers — The lowest cost also have a limited number of life cycles, 50 to 100 million maximum.
- Magnetostrictive — Infinite life cycles, convenient for mounting integral to cylinder, long strokes available, repeatability typical ±0.02% to ±0.05% of full range.
- LVDT’s — Infinite life cycles, highest accuracy, highest reliability, available in AC or DC types. AC types require additional signal conditioner from manufacturer.
Angular Position Feedback — These devices are available from manufacturers of linear potentiometers and LVDTs. Operational characteristics are similar to the linear versions.

Pressure Transducers — These are available in low and high level outputs. The low level type require additional amplification.

Tachometers — Available in ratings of volts per thousand RPM. The proper selection is determined by the speed range of the application, and the availability of a gearbox or belt drive system. A zero backlash drive system and coupling design is required for servo applications. The belt drive system provides less backlash than gears. The minimum allowable tachometer velocity is 40 RPM typical. The maximum RPM output of the belt drive system should be designed to produce approximately 10 volts tachometer output (can be scaled by feedback gain). DC tachometers only.

Feedback Coupling
Of the many machine design parameters involved with applying servo hydraulics the feedback coupling has the most significant impact on overall system accuracy. Care should be taken in the design and assembly of mechanical links such as gear backlash or LVDT mounts, to avoid any lost motion. Any actuator movement which may occur without causing a proportional change in feedback voltage will directly add to the error budget.

Servovalve Sizing
Determining the proper size of servovalve per application is as important as selection of electronic system components. In hydraulic applications it is recommended that a 1000 psi pressure drop be allowed to the valve, at full flow. This will result in the remaining system pressure being usable for moving the actuator and load. Determine the maximum flow requirement of the system carefully, as over-sizing a servovalve can defeat the accuracy potential of your system. In retrofit systems where system pressure is limited, it is sometimes necessary to use a larger servovalve to minimize pressure drop in the valve.

Actuator Consideration
Actuator selection criterion for servo applications are:
1. Low break-away force.
2. Low running friction, smooth and consistent throughout stroke.
3. Minimum active area difference if possible.

Filtration
Servovalve life expectancy is a function of oil cleanliness. Parker flushing valves allow bi-directional movement of actuator, and high pump throughput at the same time. This flushing procedure, along with the use of a 3-5 micron filter mounted close to the servovalve, will extend system life. The recommended cleanliness level is ISO 4572-1981-8/10, SAE Class 3, ISO Code 15/12, or better.
Position Servo Control

One 23-7030 Control Amplifier may be used per axis for position control of linear actuators. The position command as shown will provide a ±15 Volt signal. Some span adjustment will be necessary (see section on command and feedback alignment). If the feedback device being used has 0 to +10V output, modify wiring to produce a compatible (0 to +15V) command signal, and adjust the span for 0 to +10V at T.P.A.

Typical Set-Up Procedure:

1. Align command and feedback signals. Adjust current driver and offset (page 8).
2. Adjust error gain pot (R11) to approximately 25% or 4 turns CW from full CCW rotation.
3. Set the load to the center position. Set the command pot to the center position.
4. Apply power to the amplifier. Apply hydraulic supply pressure to the servovalve.
5. The actuator should center itself. If the load runs away from center, swap the wires from terminal strip connectors N and O or card edge pins 1 and 3 to the servovalve.
6. With a quick small (20%) change back and forth on the command pot, observe the actuator motion. Slowly adjust the error gain (R11) clockwise for maximum system resolution. If load begins to chatter, overshoot excessively, or oscillate, reduce gain by adjusting R11 counter clockwise until system stabilizes. Proper adjustment of R11 will optimize the system for accuracy, stiffness, and bandwidth. On smaller, high frequency actuators it may be possible to replace potentiometer R11 with a higher value, thus extending the range to its optimum.

Any type of analog position sensor may be used. Magnetostrictive Probes, LVDTs, Linear Potentiometers, and String Pots may all provide a compatible output signals.
90° Rotary Actuator – Position Control Application

One feedback potentiometer (position sensor) commonly used with rotary actuators is the Midori P/N CP-2FK(b)-5K. The CP-2FK (pot) has a mechanical travel of 360° without stops, and an electrical travel of 330°. Alignment of the feedback pot is as follows:

Dismount servovalve. Apply the ±15V power supply voltages across the pot element. Connect a volt meter between the pot wiper and power supply signal common. Loosen the clamps that hold the pot from rotating in the manifold. Rotate actuator end to end, noting the voltage measured at the wiper. Rotate the pot slightly, then hold the pot in place while again checking wiper voltage at each end of stroke. Continue this procedure until the output voltage is symmetrical about zero. Approximate output signals should be ±4V for 90° of total rotation.

Command and feedback alignment procedure for the amplifier can now be performed to match the command signal to the pot wiper voltage at test points T.P.A. and T.P.B. respectively.

With the system connected per the example, apply a zero volt command signal (this should represent 45°), apply supply pressure and 120 VAC power. If the system stops at center of stroke, the valve phasing is correct. If the system goes to one end of stroke and stays, swap the two valve control current wires.

Once proper polarity has been established, apply an alternating command voltage to produce a cyclic motion of ±1/4 stroke. Slowly adjust the Error Gain pot clockwise to increase system response. At some point in this adjustment, the actuator position may become unstable. Reduce the error gain (CCW) to maximum stable value (with full payload).

Full command signal range should result in full travel. The F.B. Gain or Span pots may need to be adjusted to produce full travel.
### Force Control from Differential Pressure Feedback

Differential pressure feedback can be used to produce an actuator output force which is linear and proportional to the applied command signal. As a closed loop system, the output force is much less sensitive to supply pressure fluctuations. Offset for rod vs. blind piston area must be accounted for.

The servo amplifier determines the pressure error by comparison of the pressure command (requested) signal to the pressure sensor (measured) signal. The servovalve responds to the error signal by controlling fluid delivery into and out of each end of the actuator.

Set up requires that the signal types for command and feedback be of compatible types.

The example shown produces a ±10V command signal. This is compatible with pressure sensors having output signals of ±5 VDC or ±10 VDC at full pressure, by adjustment of the feedback gain.

If constructed as shown, start up as follows:

1. Apply 120 VAC to amplifier and apply pressure to the servovalve.
2. Set command signal to 50%. Monitor signal at pressure sensor output.
3. If monitored signal does not follow, swap wires to servovalve between N and O.
4. Move command signal up and down. Verify that sensor signal follows.
5. Move command signal to maximum and adjust F.B. gain for maximum desired force output.
6. Move command signal up and down while adjusting error gain pot clockwise.
7. If system becomes unstable, reduce direction of error gain adjustment until stability is re-gained.

Maximum system accuracy comes from using as much Error Gain as possible without instability.
Often when the servo loop is closed digitally, the output of the digital device (programmable controller, process computer, etc.) is not capable of directly operating a servovalve. The 23-7030 may be used as an “open loop” in-line amplifier to increase the analog signal power level, and provide bi-directional current to the servovalve.

In this application a 4-20 mA signal is converted to produce valve null (no flow) at 12 mA, and full flow at 4 mA and 20 mA respectively. It is most helpful if two current meters are available for set-up, one in series with the 4-20 mA command loop, and the other in series with the servovalve output cable.

1. Move Jumper J1 to the I (Current Input) position (towards the span pot). This will place a 250 ohm load in series with the 4-20 mA command loop.
2. Connect terminal strip terminals D to L (or card edge pin 6 to 15) with a short piece of wire.
3. Adjust Span (R2), Error Gain (R11), and Signal Offset Reference (R7) to 50% rotation (visual).
4. Connect the 4-20 mA source to terminal J (or card edge pin 8), with a current meter in series. Connect the 4-20 mA return signal to terminal H (or card edge pin 12).
5. Connect the servovalve (reference page 9 for wiring instructions).
6. Apply 120 VAC to terminals B and C (or card edge pins 18 and 20).
7. Apply a 12 mA command signal.
8. Adjust span potentiometer R2 for 0.0V at T.P.C.
9. Change the command signal to 4 mA, and adjust the error gain pot R11 for 12.0 VDC at T.P.C.
10. Adjust the current limit (R23) until a current meter displays the maximum mA rating to the servovalve. Change the command input signal to 20 mA and verify a polarity change in the current to the servovalve. The magnitude should be symmetrical within 2-3%.
11. Repeat steps 5 thru 8 as required to achieve repeatable results.
Typical Applications

Position Control

Velocity Control

Force/Differential Pressure Control

±10V Signal Conditioner

4-20 mA Signal Conditioner

Master/Slave Position Follower
Offer of Sale

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1. Terms and Conditions of Sale: All descriptions, quotations, proposals, offers, acknowledgments, acceptances and sales of Seller’s products are subject to and shall be governed exclusively by the terms and conditions stated herein. Buyer’s acceptance of any offer to sell is limited to these terms and conditions. Any terms or conditions in addition to, or inconsistent with those stated herein, proposed by Buyer in any acceptance of an offer by Seller, are hereby objected to. No such additional, different or inconsistent terms and conditions shall become part of the contract between Buyer and Seller unless expressly accepted in writing by Seller. Seller’s acceptance of any offer to purchase by Buyer is expressly conditional upon Buyer’s assent to all the terms and conditions stated herein, including any terms in addition to, or inconsistent with those contained in Buyer’s offer. Acceptance of Seller’s products shall in all events constitute such assent.

2. Payment: Payment shall be made by Buyer net 30 days from the date of delivery of the items purchased hereunder. Amounts not timely paid shall bear interest at the maximum rate permitted by law for each month or portion thereof that the Buyer is late in making payment. Any claims by Buyer for omissions or shortages in a shipment shall be waived unless Seller receives notice thereof within 30 days after Buyer’s receipt of the shipment.

3. Delivery: Unless otherwise provided on the face hereof, delivery shall be made F.O.B. Seller’s plant. Regardless of the method of delivery, however, risk of loss shall pass to Buyer upon Seller’s delivery to a carrier. Any delivery dates shown are approximate only and Seller shall have no liability for any delays in delivery.

4. Warranty: Seller warrants that the items sold hereunder shall be free from defects in material or workmanship for a period of 18 months from date of manufacture by Parker Hannifin Corporation. THIS WARRANTY COMPRISSE THE SOLE AND ENTIRE WARRANTY PERTAINING TO ITEMS PROVIDED HEREREUNDER. SELLER MAKES NO OTHER WARRANTY, GUARANTEE, OR REPRESENTATION OF ANY KIND WHATSOEVER. ALL OTHER WARRANTIES, INCLUDING BUT NOT LIMITED TO, MERCHANTABILITY AND FITNESS FOR PURPOSE, WHETHER EXPRESS, IMPLIED, OR ARISING BY OPERATION OF LAW, TRADE USAGE, OR COURSE OF DEALING ARE HEREBY DISCLAIMED. NOTWITHSTANDING THE FOREGOING, THERE ARE NO WARRANTIES WHATSOEVER ON ITEMS BUILT OR ACQUIRED WHOLLY OR PARTIALLY, TO BUYER’S DESIGNS OR SPECIFICATIONS.

5. Limitation Of Remedy: SELLER’S LIABILITY ARISING FROM OR IN ANY WAY CONNECTED WITH THE ITEMS SOLD OR THIS CONTRACT SHALL BE LIMITED EXCLUSIVELY TO REPAIR OR REPLACEMENT OF THE ITEMS SOLD OR REFUND OF THE PURCHASE PRICE PAID BY BUYER, AT SELLER’S SOLE OPTION. IN NO EVENT SHALL SELLER BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL, CONTINGENT OR SPECIAL DAMAGES OF ANY KIND OR NATURE WHATSOEVER, INCLUDING BUT NOT LIMITED TO LOST PROFITS ARISING FROM OR IN ANY WAY CONNECTED WITH THIS AGREEMENT OR ITEMS SOLD HEREREUNDER, WHETHER ALLEGED TO ARISE FROM BREACH OF CONTRACT, EXPRESS OR IMPLIED WARRANTY, OR IN TORT, INCLUDING WITHOUT LIMITATION, NEGLIGENCE, NEGLIGENCE, FAILURE TO WARN OR STRICT LIABILITY.

6. Changes, Reschedules and Cancellations: Buyer may request to modify the designs or specifications for the items sold hereunder as well as the quantities and delivery dates thereof, or may request to cancel all or part of this order, however, no such requested modification or cancellation shall become part of the contract between Buyer and Seller unless accepted by Seller in a written amendment to this Agreement. Acceptance of any such requested modification or cancellation shall be at Seller’s discretion, and shall be upon such terms and conditions as Seller may require.

7. Special Tooling: A tooling charge may be imposed for any special tooling, including without limitation, dies, fixtures, molds and patterns, acquired to manufacture items sold pursuant to this contract. Such special tooling shall be and remain Seller’s property notwithstanding payment of any charges by Buyer. In no event will Buyer acquire any interest in apparatus belonging to Seller which is utilized in the manufacture of the items sold hereunder, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special tooling or other property in its sole discretion at any time.

8. Buyer’s Property: Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which become Buyer’s property, may be considered obsolete and may be destroyed by Seller two (2) consecutive years have elapsed without Buyer placing an order for the items which are manufactured using such property, Seller shall not be responsible for any loss or damage to such property while it is in Seller’s possession or control.

9. Taxes: Unless otherwise indicated on the face hereof, all prices and charges are exclusive of excise, sales, use, property, occupational or like taxes which may be imposed by any taxing authority upon the manufacture, sale or delivery of the items sold hereunder. If any such taxes must be paid by Seller or if Seller is liable for the collection of such tax, the amount thereof shall be in addition to the amounts for the items sold. Buyer agrees to pay all such taxes or to reimburse Seller therefore upon receipt of its invoice. If Buyer claims exemption from any sales, use or other tax imposed by any taxing authority, Buyer shall save Seller harmless from and against any such tax, together with any interest or penalties thereon which may be assessed if the items are held to be taxable.

10. Indemnity For Infringement of Intellectual Property Rights: Seller shall have no liability for infringement of any patents, trademarks, copyrights or similar rights except as provided in this Part 10. Seller will defend and indemnify Buyer against allegations of infringement of U.S. Patents, U.S. Trademarks, copyrights, trade dress and trade secrets (hereinafter ‘Intellectual Property Rights’). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on an allegation that an item sold pursuant to this contract infringes the Intellectual Property Rights of a third party. Seller’s obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If an item sold hereunder is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at its sole expense and option, procure for Buyer the right to continue using said item, replace or modify said item so as to make it noninfringing, or offer to accept return of said item and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for an agreement based on information provided by Buyer, or directed to items delivered hereunder for which the designs are specified in whole or in part by Buyer, or infringements resulting from the modification, combination or use in a system of any item sold hereunder. The foregoing provisions of this Part 10 shall constitute Seller’s sole and exclusive liability and Buyer’s sole and exclusive remedy for infringement of Intellectual Property Rights. If a claim is based on information provided by Buyer or if the design for an item delivered hereunder is specified in whole or in part by Buyer, Buyer shall defend and indemnify Seller for all costs, expenses or judgments resulting from any claim that such item infringes any patent, trademark, copyright, trade dress, trade secret or any similar right.

11. Force Majeure: Seller does not assume the risk of and shall not be liable for delay or failure to perform any of Seller’s obligations by reason of circumstances beyond the reasonable control of Seller (hereinafter ‘Events of Force Majeure’). Events of Force Majeure shall include without limitation, accidents, acts of God, strikes or labor disputes, acts, laws, rules or regulations of any government or government agency, fires, floods, delays or failures in delivery of carriers or suppliers, shortages of materials and any other cause beyond Seller’s control.

12. Entire Agreement/Governing Law: The terms and conditions set forth herein, together with any amendments, modifications and any notices or terms or conditions accepted by Buyer, shall constitute the entire Agreement concerning the items sold, and there are no oral or other representations or agreements which pertain thereto. This Agreement shall be governed in all respects by the law of the State of Ohio. No actions arising out of the sale of the items sold hereunder or this Agreement may be brought by either party more than two (2) years after the cause of action accrues.