C31015
Rev 2.2.2001

APPLICATION NOTES

G122 - 202 GENERAL PURPOSE

P I D SERVOAMPLIFIER

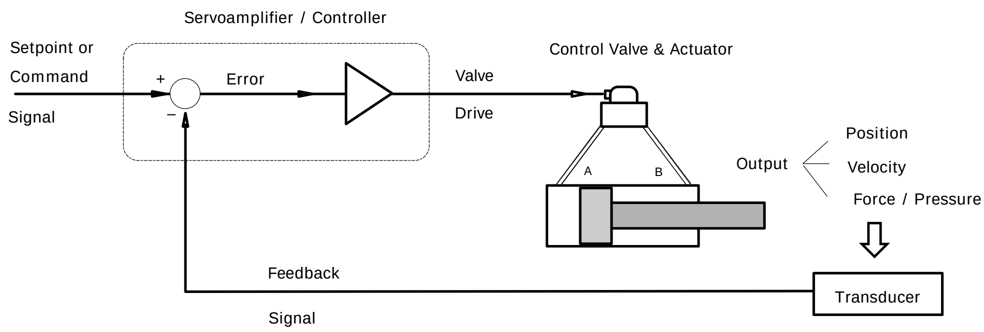
MOOG

INDEX

2 TYPICAL ELECTROHYDRAULIC CLOSED LOOP CONTROL

The MOOG GENERAL PURPOSE P I D SERVOAMPLIFIER G122-202 is a Eurocard format servoamplifier for closed loop control with an electro-hydraulic control valve, a hydraulic actuator and a transducer with an analog output.

It is designed to be flexible to cater for all variety of loops, namely for position, velocity or force/pressure control.



Typical Closed Loop Structure

The transducer can be a magnetostrictive, potentiometric or DCDT type. The control valve can be a servo or proportional valve, either with a current or voltage drive signal.

The block diagram shows the elements needed for a Closed Loop Control system. The main feature of a closed loop control system is that the actual output is compared to the desired output, called the Set-point or Command signal. If an error exists, the Controller acts to counter it and reduce it to as close to zero as possible.

In comparison, an Open Loop Control does not take account of what the output does. It cannot automatically correct if different conditions exist that change the output.

Set-point or Command

– The Set-point signal, variously called the Command or Reference signal, is the input to the Close Loop Control system. It is typically a DC voltage proportional to the output required.

Transducer and Feedback signal

– The Transducer monitors the output and produces a Feedback signal to be compared with the Command signal. Typically transducers are available for distance, velocity, force and pressure and they convert the measured characteristic to a DC voltage.

Servoamplifier or Controller

– The Servoamplifier or Controller compares the Set-point signal, ie., the required output, with the actual output to produce an error and then uses this to try to reduce the error to zero.

Control valve and Actuator

– The Control valve receives a signal related to the error signal. The valve output then changes the Actuator output in the right sense to reduce the error.

Note: because the G122-202 is a general purpose servoamplifier these notes cannot cover all possible applications. They can only give guidelines for general cases. For cases that are not covered and where the notes cannot be extrapolated, please contact a Moog Application Group.

3 CHECK LIST FOR SUCCESSFUL CLOSED LOOP CONTROL

The check list below summarises the points that have to be covered for a successful closed loop. It could also serve as a check list for discussions with component suppliers.

3.1 CLOSED LOOP CONTROL SYSTEM DESIGN

- Purpose of system is defined. ☐
- System: – force, velocity & sometimes acceleration specification. ☐
- Hydraulics: – pressure and flow. ☐
- Control: – dynamic response, static or dynamic accuracy. ☐
- Pay-back period / value of job: - indicative of money that can be spent. ☐
- What has to be controlled? Can you specify it clearly? ☐
- Is the job straight forward or is it at the edge of what is achievable? How does one tell? ☐
- Do you know if it is easily achievable? ☐
- Is this a critical job where the performance is critical? ☐
- Do you need a guaranteed performance? ☐
- Do you need a component supplier or a system supplier? ☐

Note the typical warning signs of a difficult system:

- The mass to be moved is large. ☐
- Both high speed & high accuracy are required. ☐

3.2 SERVOCONTROLLER SELECTION

- Dedicated or General? ☐
- Command Type ☐
- Feedback Transducer Type and output. ☐
- Output Drive Type (based on control valve selection). ☐

3.3 CONTROL VALVE SELECTION

What is important for your application?
Consider the following technical characteristics;

- Size: Flow and pressure, drive signal. ☐
- Response: frequency and step response. ☐
- Spool null cut
  - Axis cut, ie. zero overlap and underlap ☐
  - Overlap ☐
  - Underlap/Motor Spool, ie. overlap to P and underlap to T ☐
  - risk of cavitation ☐
- Spool control
  - Open loop ☐
  - Mechanical Feedback ☐
  - Electrical Feedback ☐
- Spool control accuracy: threshold, hysteresis, flow forces ☐
- Service availability ☐

In summary, the choice is based upon;

- Flow Size and pressure ☐
- Spool null cut ☐
- Response ☐
- Spool control accuracy ☐
- Back-up, delivery and price ☐

3.4 ACTUATOR SELECTION / SPECIFICATION

Specify the actuator from the following technical characteristics:

- Displacement: Cylinder - cm^2 [in^2] or Motor - cm^3 [in^2]/ rev ☐
- Mounting ☐
- Speed, see seals ☐
- Side loads (best absorbed elsewhere) ☐
- Fluid type ☐
- Environment ☐
- Seal Type
  - normal elastomer ☐
  - low friction elastomer ☐
  - laminar fluid bearing ☐
  - hydrostatic fluid bearing ☐
- Friction specification, stick-slip, turnaround smoothness ☐

3.5 ANCILLARY VALVES

Ancillary valves are used to supplement the control valve.

Avoid modulating valves in between the control valve and the actuator. They can interfere in an unpredictable manner with the closed loop.

Examples:

- “Load holding” if the closed loop is turned off
  - Note the need to consider the nature of the transition from open loop back to closed loop. ☐
  - Use externally drained pilots for pilot operated check valves. ☐
- “Pressure limiting” and “anti-cavitation”. ☐

3.6 TRANSDUCER SELECTION

Is this a critical application? ☐
Do you need expert advice on any of the points mentioned above or below? ☐

- Linearity ☐
- Response ☐
- Total accuracy, including hysteresis and temperature drift ☐
- Immunity to electrical noise ☐
- Mechanical life ☐

3.7 INSTALLATION

- Electrical
  - shielding of cables, type of shielding ☐
  - routing of cables to avoid electrically noisy sites ☐
  - mounting of electronics; noise and thermal considerations ☐
  - flexible cable choice and connector strain relief ☐
  - wire terminations, use ferrules, do not solder ☐
- Hydraulic
  - valve mounting, location / orientation ☐
  - minimum line volume between valve and actuator = max. stiffness ☐
  - minimum line dia. = min. volume, trade off the pressure drop ☐
- Mechanical
  - minimum backlash ☐
  - maximum stiffness ☐
  - minimum friction and stick-slip friction ☐
- Pressure Transducer
  - mount as close as possible to control valve to avoid line dynamics ☐
  - mount lower than control valve to promote self bleeding ☐
  - be wary of long (typical ID 1 mm) test lines as these create delays ☐

3.8 OIL FILTRATION

Oil Cleanliness Target:

- The cleanliness level is specified using the ISO 4406 standard. Typical minimum values for valve operation are 16/13 to 15/11. Typical values suggested for long valve life are 14/11 to 12/9.

Filtration Strategy

- To achieve the above Oil Cleanliness Target, a number of filtration strategies is possible. One such strategy follows:
  - Full flow, no bypass, high pressure rated filter. This is mounted as close as possible to the valve as a last chance filter to protect the valve against stray particles. It does not clean the oil. ☐

    Filter Rating: Beta_15 to Beta_25 > 75
  - Return flow or recirculation filter, to clean the oil and ensure control valve life.

    Filter Rating: Beta_3 to Beta_6> 75 ☐
  - If return line flow filtration is less effective due to varying flows, an easy alternative is constant flow bleed-off low pressure filtration.
- Frequent initial monitoring plus regular planned monitoring of the resultant oil cleanliness will provide feedback on the effectiveness of the strategy chosen.
- Regular oil cleanliness monitoring as well provides early warning of component failure. This protects the system from down-time and the control valve from expensive damage.

3.9 HYDRAULIC POWER UNIT

– Constant supply pressure is important if accurate pressure or force control is required. Sudden pressure changes will pass straight through the control valve and be felt at the load.

Flow & Best Pressure Control Options

- Fixed pump & relief valve ☐
- Pressure compensated pump ☐
- Consider an accumulator if the pump response will (i) limit or (ii) interfere with the control. ☐

– Less critical applications could use a fixed pump and unloading circuit. A soft switching unloading valve can help reduce the pressure shocks.

Flow & General Pressure Control Options

- Fixed pump, accumulator and unloading valve ☐
- Soft-switching unloading valve ☐

3.10 SERVICE

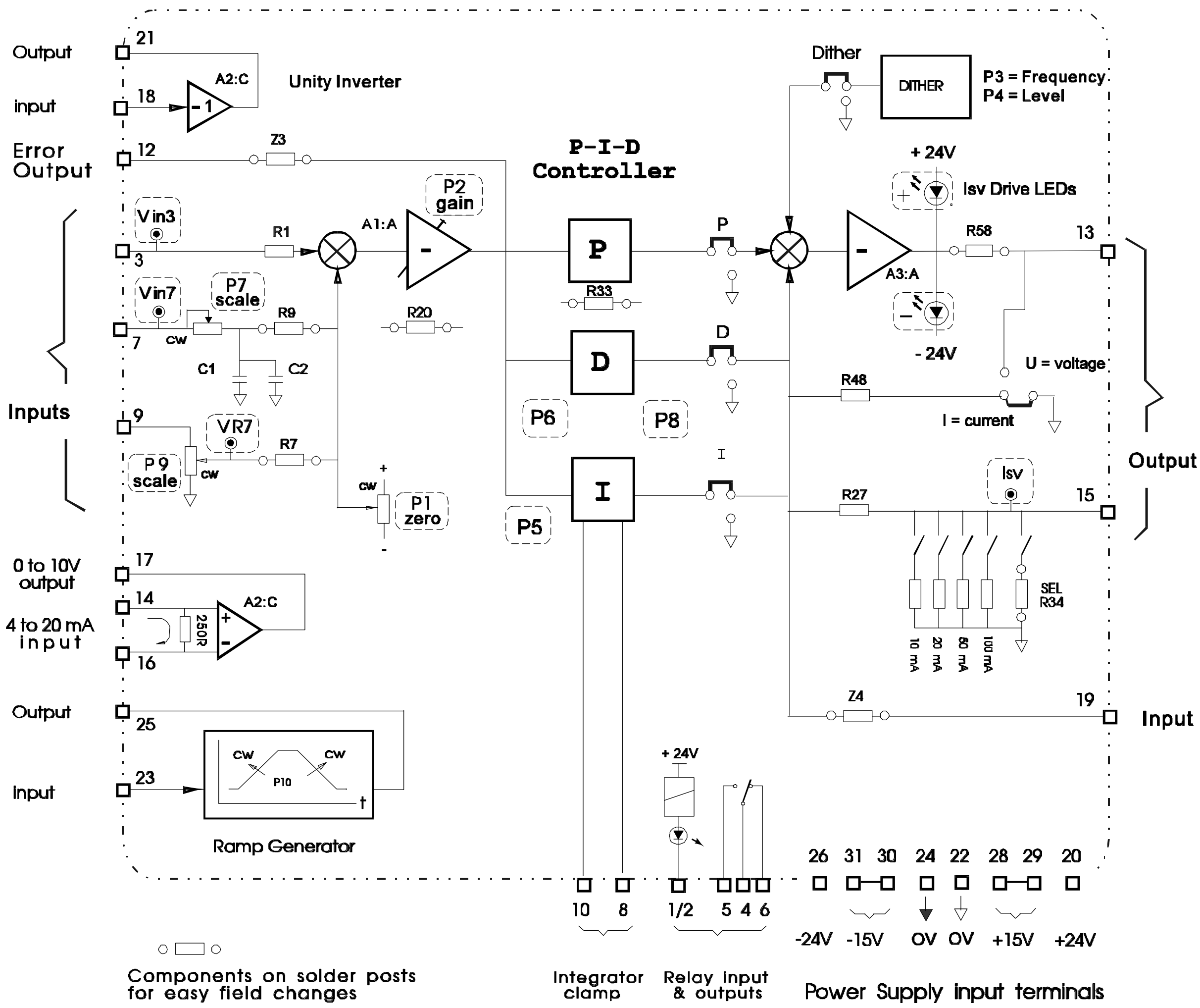
– How critical is this application? ☐

– What spares are necessary? ☐

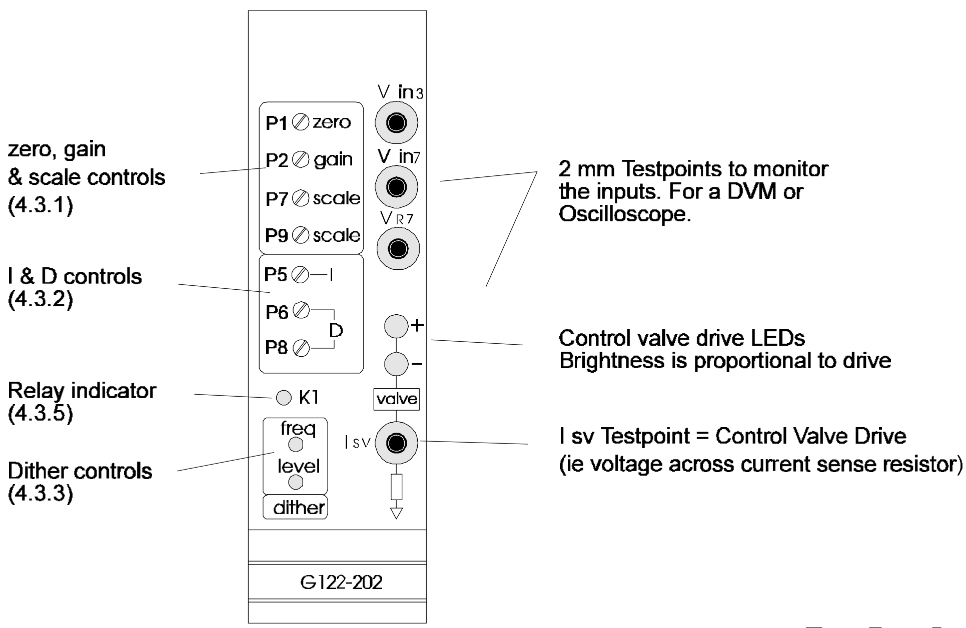
– Service Facility availability: Your first choice should not be to send a Servocontroller to a TV repair man nor a Servovalve to a conventional hydraulic shop. ☐

4 DETAILED DESCRIPTION

4.1 GENERAL BLOCK DIAGRAM



4.2 FRONT PANEL



4.3 CIRCUIT DESCRIPTION

4.3.1 SUMMING AMPLIFIER A1:A

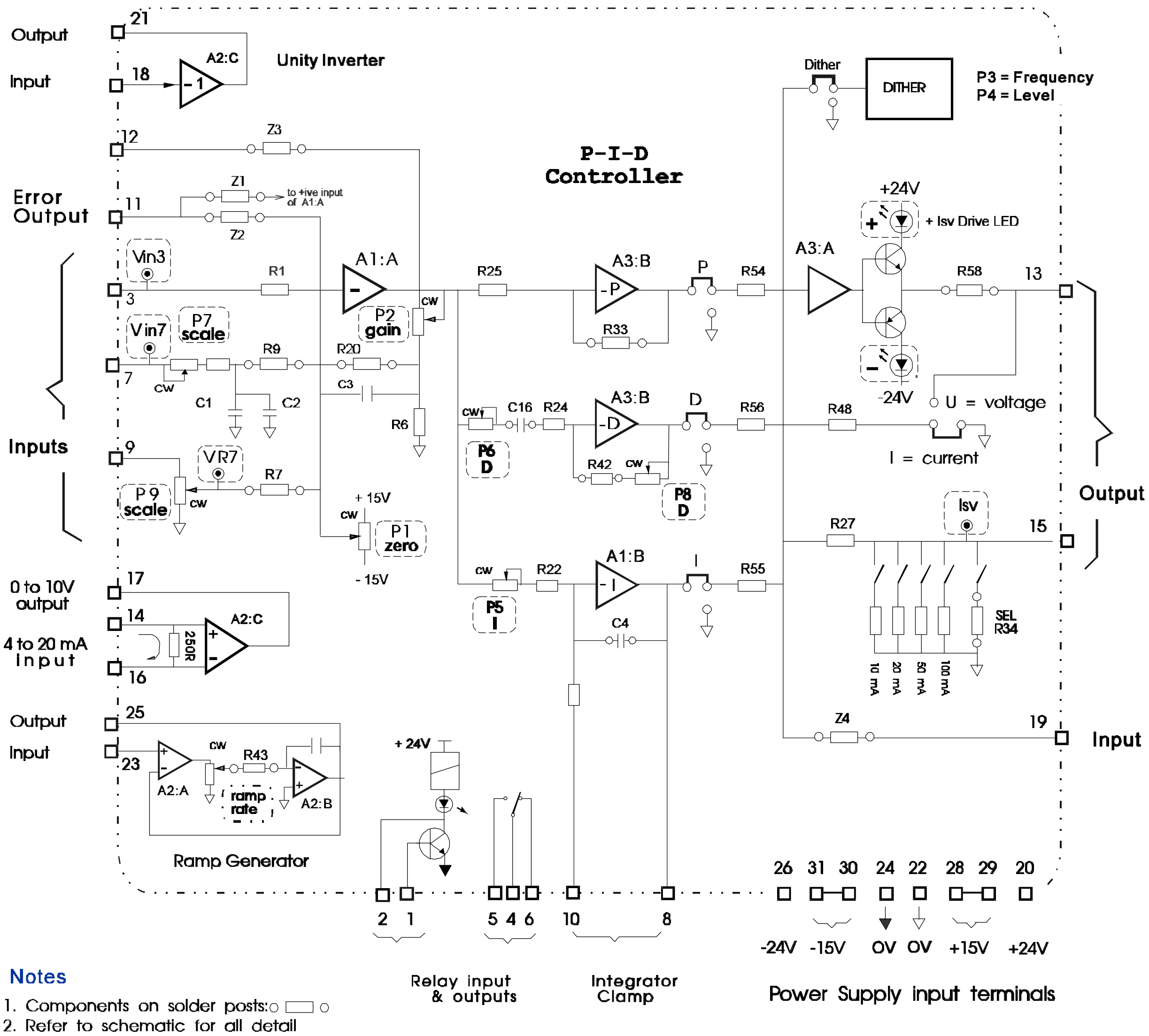
4.3.1.1 Set-point Input, pin 7, Scale pot P7 and Testpoint V in7

- The 100k **scale** pot P7 allows scaling of the command signal to match the feedback signal. Clockwise (CW) rotation increases the resistance of P7 and reduces the command signal.

- Capacitors C1 & C2 provide a low pass filter on the set-point signal. This is useful to soften a step change in the set-point or when a ramped set-point or command is not available. Similarly it can be used to remove electrical noise on the command signal. Remove C1 and C2 to remove this time constant. See Section 5.2 for the location diagram.

	Capacitor	Value	≈Time constant with P7 at mid position	≈ Break Frequency with P7 at mid position
	C1	1UF	25 ms	6 Hz
	C2	2U2F	50 ms	3 Hz
As supplied	C1 + C2	3U2F	80 ms	2 Hz

- R9, input resistor on solder posts = 47k. Increase if feedback signal is too big with P7 fully CW. Decrease if feedback is too small with P7 fully CCW.



DETAILED BLOCK DIAGRAM

4.3.1.3 Feedback Input, pin 3 with Testpoint Vin3

- Feedback polarity must be opposite to Set-point / Command polarity
- Input resistor R1 = 100k ±1%

4.3.1.4 Feedback Input, pin 9 and **scale** pot P9 with Testpoint V_{R7} (alternative feedback input)

- Input 9 is often used for high voltage feedback signals where the **scale** pot P9 is used to divide the signal down.
- Testpoint V_{R7} shows the divider output.
- Clockwise rotation of the **scale** pot P9 reduces the signal at Testpoint V_{R7} and would increase the feedback signal.
- R7 = 100k and is on solder posts.

4.3.1.5 **zero** pot P1 and amplifier input R4

- This pot supplies a + or – input to compensate for small zero errors in the system.
- R4 can be decreased in value from 2M2 to increase the range of adjustment.

4.3.1.6 **gain** pot P2, R20, C3

- The **gain** pot P2 varies the amplification of the error signal by the summing amplifier.
- R20, on solder posts = 100k: It sets the minimum gain. It can be increased to increase the minimum gain of the summing amplifier.
- C3 = 10 nF: It is in parallel with R20 and rolls off the frequency response of the summing amplifier. The resultant time constant of 1 ms gives a bandwidth of 150 Hz which for most systems is not a limitation. If Hi-response valves are being used and it is feared that this time constant could limit the system response, consider removing C3 altogether or replacing it with a smaller value, if electrical noise proves a limitation.

  If noise exists on the command, C1 and C2 can be used to limit its influence. This is preferred to increasing C3 because this “noise filter time constant” is outside the loop and hence will not influence loop stability.

  If noise exists on the feedback, C3 can be increased to reduce the noise getting through to the output. Naturally the effect on the closed loop control of this time constant must be considered. For example, C3 = 100 nF gives a roll-off frequency of 15 Hz and could be used without degrading a position or velocity loop where the hydraulic - mass natural frequency was less than 10 to 20 Hz.

4.3.1.7 Input, pins 11, Z1 and Z2. Not loaded, refer to full schematic.

- Z1 provides an input path to the non-inverting input of A1:A
- Z2 provides another input path to the inverting input of A1:A

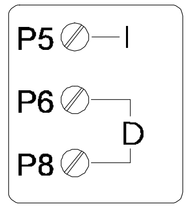
4.3.1.8 Input, pin 19, Z4.

- Can be used as a “disturbance” input to tune the loop. Solder a resistor into the Z4 location to give 25% to 50% of rated Isv when pin 19 is connected to + or - 15V supply . This can be done via a switch or by hand, with a piece of wire.
- For example, if Z4 = 300 kOhms then +15V will produce - 0.5V at the Isv Testpoint corresponding to 25 mA when the I-current link and 50mA full scale Isv (see 4.3.4.2) is selected. Now, 25 mA corresponds to 50% of a control valve with 50 mA rated current.
- Z4 is loaded with 1M0hm when shipped.

Z4	Volts	delta Isv if 50 mA range selected
100k	1.5 V	75 mA
150K	1 V	50 mA
300K	0,5 V	25 mA
620K	≈ 0.25 V	12 mA
750K	0.2	10 mA
1M5	0.1	5 mA

4.3.2 P – I – D CONTROLLER

- Parallel structure, link selectable
- Gain Pot P2 changes the gain level for the total P-I-D



I & D controls

4.3.2.1 P–Proportional

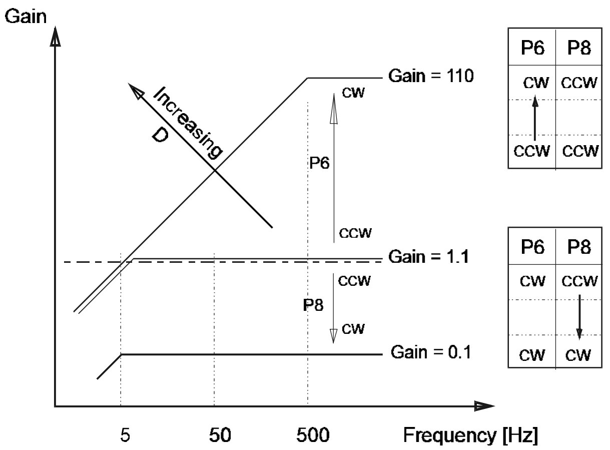
- gain = 1, fixed.

4.3.2.2 I–Integral

- P5 = Integral gain pot, Clockwise (CW) rotation increases the Integral gain.
- See also 4.3.5 for Relay to clamp the Integrator to zero.

4.3.2.3 D–Derivative

- P6 is a pot in the input in series with C 4 to produce the breakpoint time constant. Clockwise (CW) rotation decreases the pots resistance and increases the breakpoint frequency. As the same time, it increases the gain beyond the breakpoint frequency.
- P8 is a pot in the feedback path, CW rotation decreases the pot's resistance and decreases the gain of the frequency dependent characteristic set by P6.



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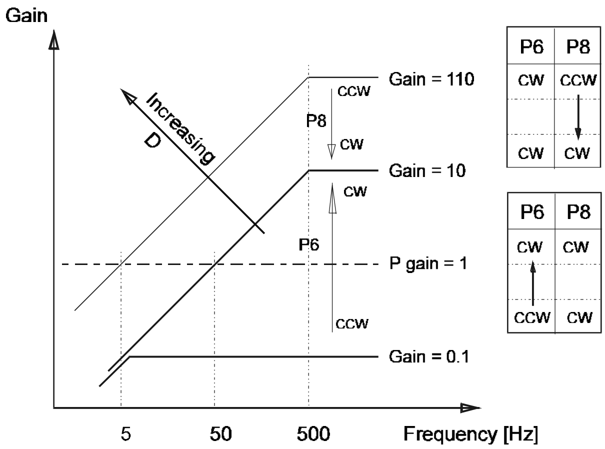
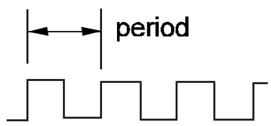


(ii)

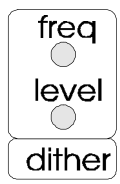
- Note that the high frequency gain is set by the ratio of P8 / P6. Reduce the high frequency gain if high frequency signal noise is being amplified excessively and causing the Isv LEDs to be both on and the control valve to hum.

4.3.3 Dither

- The Dither signal is a ≈ 25 Vpp square wave signal produced by A3:D configured as a free-running multivibrator.
- Dither is an oscillating signal whose purpose is to keep an element continually moving. This is to avoid or minimise stick-slip phenomena in this component. A typical use is to lower the threshold of the spool in a control valve.
- Dither is generally not needed for position control using standard Moog low threshold servo or proportional valves. Only in the case of ultra low friction drives will the Moog control valve threshold be a limiting factor.
- Similar applies to velocity loops.
- For pressure control, Dither can provide the ultimate in pressure resolution with a trade–off in reduced Servovalve life. When used with a Moog valve, the peak-peak value is typically kept less than 20% of the rated current.



Dither Signal



4.3.3.1 ON - OFF LINK

– The Link “Dither ON / OFF” enables or disables the free-running multivibrator.

4.3.3.2 **freq.** pot **P3**

– Clockwise rotation increases the frequency from 25 Hz to 320 Hz.

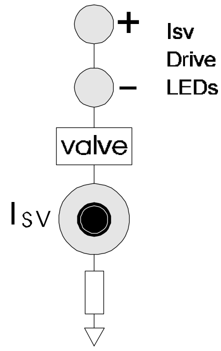
4.3.3.3 **level** pot **P4**

– Clockwise rotation of P4 increases the Dither signal level. Measure the amplitude at Testpoint Isv with an oscilloscope.

4.3.4 Current Stage, A3:A, Q2 & Q3.

– The Current Stage uses the voltage generated by the current flowing over the selected current sense resistor, as feedback to minimise the inductive time constant of the servovalve coils and make the current independent of the temperature dependent coil resistance.

4.3.4.1 Isv Drive LEDs “+” and ”–”



– LEDs “+” and ”–” indicate polarity and amplitude of the current or voltage drive to the control valve. They can be used during commissioning and for trouble-shooting as follows:

– If the connection to the valve is broken, no current can flow and neither LED will come on.

– In a position loop, the drive signal to an ‘axis cut’ valve will be near zero when the load is stationary. ie. both LEDs are off.

– If one LED remains on in a Position Loop, it indicates that the position error has not gone to zero, ie the Set-point cannot be reached.
  This could be due to:
  - An offset in the Servovalve (may or may not be significant) or
  - The cylinder is on its end-stop, or
  - Unusual load conditions.

– If DITHER is used, both LEDs will glow equally for zero average valve drive. Caution: Electrical noise can create the same effect!

– In a velocity loop at constant speed, one LED will glow constantly.

– Use the Drive LEDs to optimise a position loop. See section 6.7.3 Change the command signal rapidly and one Drive LED will come on until the new position is reached when it will then fade. If overshoot occurs, the other Drive LED will then flicker on momentarily. Typically adjust the LOOP GAIN with P2 for just the hint of one overshoot.

4.3.4.2 Valve Current Select Switch and Isv Testpoint

– There are five resistors, selected by the Valve Current Select Switch, that set the full scale current. The selected resistor is called the current feedback, or current sense, resistor. The current flowing through the valve produces a voltage across the current feedback resistor. This voltage is used as feedback for the output driver stage and can be monitored at the Isv Testpoint.

– Each current feedback resistor produces 1V for its rated current flow.

– The Isv Testpoint reads the voltage dropped across the current feedback resistor. This is used as a measure of valve drive for MFB valves rather than the voltage drop across the (inductive) coils.

Rated Current [mA]	Valve Current Select Switch
10	1
20	2
50	3
100	4
Select with R34	5

Aside:

"Isv" was originally used as shorthand for Current (I) and Servovalve (SV) into the coils of a MFB valve. It is used here as a generic term for "DRIVE SIGNAL TO THE CONTROL VALVE" regardless of whether it is a current or a voltage signal.

4.3.4.3 Valve current selection

Standard valves and currents

Valve current in excess of 125 to 150% of the rated current can damage MFB valves. Select the full scale valve current with SW1 to ensure that excessive current does not flow through the valve.

From the valve data sheet determine the rated current and select the current range required with the Valve Current Select Switch. If the exact rated current is not available select the next larger current range but check that 150% limit is not exceeded.

Configuring for non standard valves and currents

Where the valve has a rated current that does not fall within the standard range, it is possible to modify the output stage to suit.

The design procedure for this follows after the following Design background:

Design background

There are three resistances in series that limit the maximum current that the full scale output of ±10V can produce. They are:

- R58
- Valve coil resistance
- Current sense resistor

R58

- R58 is shipped with 68 Ohms which suits all current Moog MFB valves.
- As R58 is on solder posts on the printed circuit board, it can be easily changed if it limits the current for the valve you are using.

Valve coil resistance

- From the valve data sheet, determine the coil resistance. Typically 2 coils are used and these can be connected in series or parallel. It can be physically easier to wire in series and this is often done. Parallel connection provides redundancy and for high response valves, it maximises the amplifier-valve coil response.

Current sense resistor

- SW1 allows selection of the current sense resistor and hence the maximum output current. A number of standard currents can be selected.
- R34, is a user selectable current sense resistor to cater for other currents. It is selected by SW1_5 and is on solder posts for easy in-field modification. Note that the maximum current from the amplifier is 100 mA.

Design steps

- From the valve data sheet, determine the rated valve current and the coil resistance. Note that rated current is the current at which the valve is fully open.
- Decide whether to connect the coils in series or parallel. See the notes below for guidance.
- Select R34 so that the rated valve current produces a one volt drop across it. Note: V [Volts] = I [Amps] x R [Ohms]
- Select R38 so that the maximum valve current of 125 to 150% of rated current flows when the amplifier output is 10V.

$$\text{Imax} = \frac{10\ \text{V}}{\text{R34} + \text{Coil Resistance} + \text{R58}}$$

Notes

1. In critical applications, the coils are connected in parallel to reduce the inductive time constant and provide extra back-up in the very rare event that one coil fails open circuit.
2. High impedance coils will run into voltage limits if connected in series. Hence in these cases, either one coil is used or two connected in parallel. For example, (1000 // 1000) x (10 + 10) mA = 10V, which is close to the maximum voltage possible.

3. Low impedance coils are typically high current coils and the amplifier may run into current limits. If the current exceeds the maximum of 100 mA, use either one coil only or two connected in series. The two coil case is preferred as it will provide some second order improvement in valve null stability.

4.3.4.4 I/ U LINKS

– The links enable either a current output (I) or a voltage output (U) to be selected.

  I = current, U = voltage.

  Select either voltage or current output as required.

– Typical MFB valves have floating coils and require a current drive to both maintain (i) constant current independent of the temperature dependent coil resistance, and (ii) to reduce the inductive time lag. A voltage drive can be used but is not recommended because of the above effects.

– Control valves with on-board electronics are called Electrical Feedback (EFB) valves and have either a current or voltage input. In both cases, select “U” for voltage as follows.

  EFB valves and Current Input

  For example, some Moog proportional valves are specified as a 10 mA current drive into either 200R or 400R. The 200 or 400R input impedance is connected to ground and hence would short out the current feedback resistor and would not allow correct operation if the Servoamplifier was configured for current.

  In such cases, configure the G122-202 as a voltage (ie Link U) amplifier and adjust R48 to provide ± 2 or ± 4V as ±100% Isv. Note that a voltage drive to a low input impedance provides higher noise immunity than the same voltage drive to a high impedance input.

  EFB valves and Voltage Input

  This will be typically ± 10V into 50K nominal input impedance. The fitted value of R48 = 100K provides the necessary ± 10V nominal output.

– Values of R48 needed to limit the voltage drive for different Moog EFB valves with current inputs

Valve Signal	**R48**	
10V into 50K nominal	100K	as fitted
10 mA into 200R	2K	change R48
10 mA into 400R	3K9	change R48
10 mA into 1000R	10K	change R48

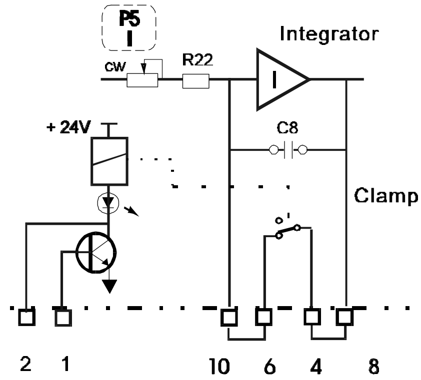
– Note that the Isv LEDs still glow proportionally to the voltage drive signal.

4.3.5 Relay

- The NO & NC Relay contacts are freely configurable.
- One application of the relay contacts is to clamp the Integrator to prevent Integrator wind-up and run-way during open-loop mode.

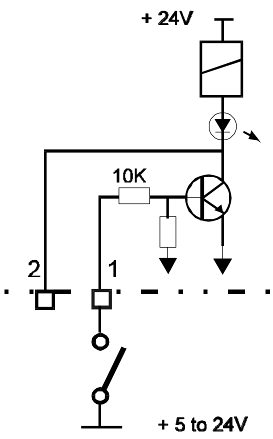
Integrator Clamp

- Refer to the block diagram on the right or the schematic of the G122-202.
- Link pin 8 to 4 and 6 to 10 and arrange to energise/de-energise the relay via either pin 1 or pin 2.



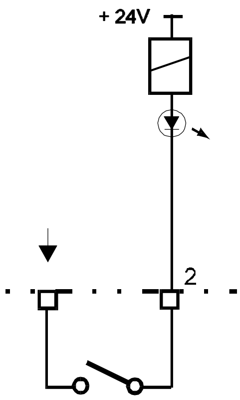
Control Input Pin 1

- Take Pin 1 high (+5 V to +24 V into 10 kOhm impedance) to energise the relay and hence enable the Integrator.
- Float or take Pin 1 to ground to de-energise the relay and so dis-enable or short the Integrator.



Control Input Pin 2

- Ground (sink ≈ 8 mA) to directly energise the relay to enable the Integrator.
- Float Pin 2 to de-energise the relay and so dis-enable or short the Integrator.



4.3.6 Unity gain inverter

The G122-202 servoamplifier requires command and feedback signals which have opposite polarities.
The unity gain inverter enables either the feedback or command signal to be inverted, if the two signals are of the same polarity. The input impedance on pin 18 is 100K Ohm and the output can drive ±12V into a minimum load of 1 K Ohm.

4.3.7 Ramp

The ramp circuit is useful in controlling the velocity of an actuator in a position loop. It is normally used to control the command signal. The circuit produces an output equal to the input but if the input is changed, the output changes at a rate set by pot P10, until the output is again equal to the input. This ramp, set by P10, has a minimum rate of 0.6 V/S and a maximum rate of 13.3 V/S. This range can be adjusted by changing R43. Increasing R43 from the 470 kOhm shipped value will slow the ramp rate. R43 should not be increased beyond 4.7 MOhm. A typical minimum value is 10 kOhm.

An application example:

– A PLC outputs a 0 to +10V position command that corresponds to a 0 to 800 mm cylinder stroke. It is required to set the cylinder velocity to 100 mm/s.

  $$100 \text{ mm/s} = \frac{100}{800} \times 10 \text{ V/S} = 1.25 \text{ V/S.}$$

  This ramp rate falls within the 0.6 to 13.3 V/S range provided with R43 = 470 kOhm. All that is needed is to set P10 to give the required rate. This can be done in two ways:

  – Input a known voltage step and measure the output voltage ramp time. A 1.0V step will ramp in 0.8 seconds when the ramp rate is 1.25 V/S.
  – With the closed loop operating, input a known step and measure the time the cylinder takes to move to the new position.

4.3.8 4 to 20 mA converter

– This circuit converts a 4 to 20 mA signal to either 0 to +10V or to 0 to -10V, depending on the input wiring polarity. 4mA gives OV and 20mA gives 10V; currents between 4 and 20mA giving a proportional voltage between 0 to 10V.

  For 0 to +10V

  – The input current is applied to pin 14 and flows out of pin 16. Pin 16 must be tied to the return line of the device generating the current.

  For 0 to -10V

  – The input current is applied to pin 16 and flows out of pin 14. Pin 14 must be tied to the return line of the device generating the current.

– The load between pins 14 and 16 is 250 Ohm.
– Care must be taken to ensure the common mode voltage on pins 14 and 16 does not exceed +12V with respect to pin 22 (0V reference). This is best achieved by connecting pin 22 to the OV reference line of the device generating the current signal.
– The output, on pin 17, can drive a minimum of 1KOhm load, with 10V output.

5 SPECIFICATION

5.1 GENERAL

Physical dimensions	EUROCARD FORMAT, 160 x 100 mm, front panel width = 35mm (7HP) Height = 128 mm (3U)
Connector	64–pin connector, DIN 41612 Type C with rows a and c linked.
Power supply	+/– 15 V @ + 75 mA / – 20 mA

Note that the –202 – is compatible with the MOOG standard Card Frames Series including the M127–102 (10 slot + power supply) and M127–105 (4 slot + power supply).

5.2 PINOUTS

Note that the pinouts generally mirror those of the F122–202 and M122–811 series of Servoamplifiers.

NAME OF SIGNAL ⇩	INPUT SPECIFICATION ⇩	PIN NUMBERS ⇩	
typically for command, not for feedback.	100K high impedance input	7	22 ground
For unlagged command, or for feedback.	100K high impedance input	3	22 ground
For unlagged command, or for feedback. Typically for high voltage input.	10K pot to ground.	9	22 ground

NAME OF SIGNAL ⇩	OUTPUT SPECIFICATION ⇩	OUTPUT PIN NUMBERS ⇩	
error signal	Z3 = 1K output impedance	12	22 ground
SERVOVALVE MFB - current drive with I = current link	±100% Servovalve current produces ± 1 V at Isv Testpoint	13	15 return to current sense resistor
EFB - both current and voltage drives with U = voltage link	±100% Servovalve drive produces ± rated voltage at pin 13. Wire pin 13 to Isv Testpoint at pin 15 (also remove R28 & R31)	13	22 ground

Power supply notes	**INPUT**	**INPUT Pin Numbers**	
	+24 V, or use + 15V if not a Moog card frame	20	
Note: all pins must be connected as shown.	**+15 V**	28 and 29	
	0 V	22,24	
	– 15 V	30 and 31	
	– 24 V, or use – 15V if not a Moog card frame	26	

MOOG

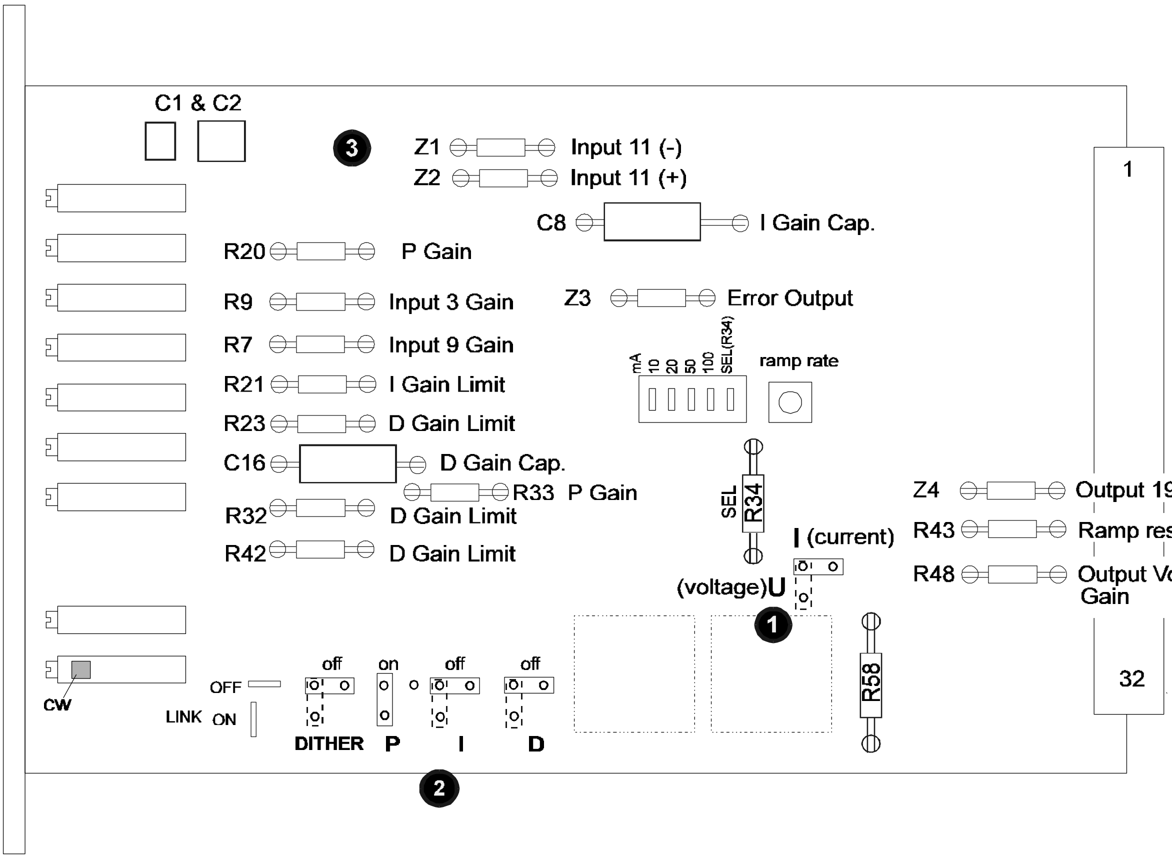
5.3 COMPONENT LOCATION DRAWING

❶ Current (I) / Voltage (U) selector links

In the card pictured, the I link has been selected ON.

Dither & P-I-D links

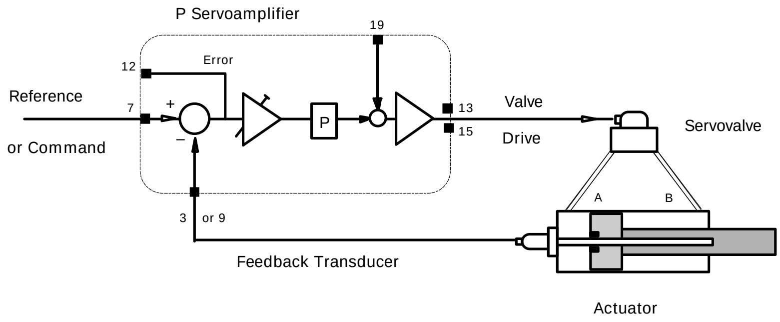
Note that if neither P nor I nor D link is vertical, ie., ON, then the amplifier can not function. In the card pictured, P link has been selected ON.



COMPONENT LOCATION

6 POSITION LOOP COMMISSIONING

6.1 CLOSED LOOP NOTES



Typical Position Loop

A typical Position Loop is shown with all of the elements needed. See section 9 for a discussion on control structures.

Sometimes the position command is ramped or slew-rate limited to produce a controlled velocity. Such a loop is not called a Velocity Loop. It is a position loop with a ramped position command and has the advantage of being able to hold position after executing a velocity profile.

A P-D Controller is assumed as the normal structure. See section 9.1.1.

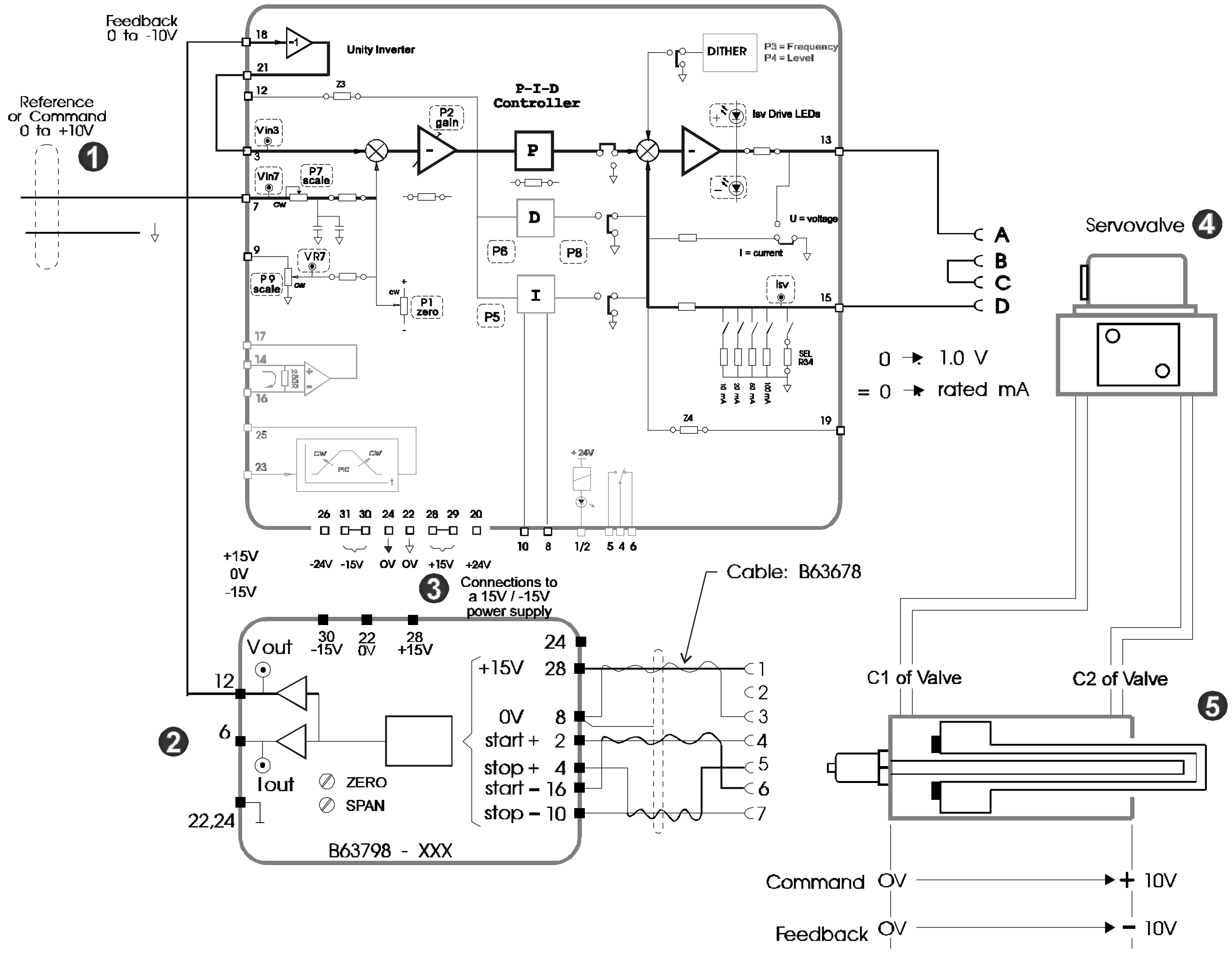
6.2 COMMISSIONING SUMMARY & CHECKLIST

The check list below is a summary of the commissioning notes in the following pages.

Use the chapter references on the right to locate the sections.

		SECTION
INTERCONNECT DIAGRAM		**6.3**
– Typical Interconnect Diagram	☐	
SERVOVALVE		**6.4**
– Use a Manual Valve Checker to drive the valve	☐	
– Verify functioning of valve	☐	
– Verify valve polarity	☐	
TRANSDUCER		**6.5**
– Drive the valve in open loop to move cylinder from end to end	☐	
– ZERO = ± .005	☐	
– SCALE = 10.0 ± .010 V	☐	
– POLARITY	☐	
CLOSED LOOP OPTIMISATION		**6.6**
– Initial set-up	☐	6.6.1
– Monitor Transducer response	☐	6.6.2
– Monitor Error or Isv response	☐	6.6.3
– Achievable Static Accuracy	☐	6.6.4
– Lead Compensation	☐	6.6.5
– Lag Compensation	☐	6.6.6
FINAL TRANSDUCER TRIM		**6.7**
– Retrim transducer to suit external position command	☐	
SERVOVALVE ADJUSTMENTS		**6.8**
–	☐	

6.3 TYPICAL INTERCONNECT DIAGRAM



TYPICAL POSITION LOOP INTERCONNECTION DIAGRAM

LOOP DESCRIPTION: the following describes a closed loop using the above typical interconnect diagram!

A typical Position Loop shown above consists of ;

❶ **Command path.** The 0 to +10 V command or reference signal is presented at pin 7. Scaling is possible with P7 and low pass filtering is effected by C1 & C2.

Feedback path. The 0 to +10 V transducer signal is fed into pin 18, inverted and the 0 to -10 V output from pin 21 goes to pin 3.

‘**P - I - D ’ Servoamplifier**

Summing amplifier. The command signal and the transducer signal are compared and the resulting error signal is amplified. The amplification is set by P2, the ‘**gain**’ potentiometer and the amplified signal can be monitored at pin 12. The amplified position error then continues through the ‘**P - I - D**’ stage, configured here as a simple **P** controller. Note also that no DITHER is used.

Output stage. The output current stage drives the valve while the front panel LEDs in the front panel *“ Isv BOX ”* indicate the polarity and the magnitude of the drive signal.

Servovalve and Actuator

The control valve ports oil to the cylinder and drives it in the commanded direction.

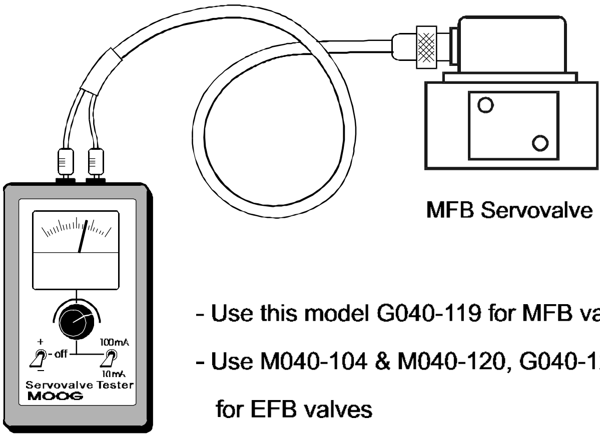
Transducer & Controller

The Position Transducer feeds back a proportional signal to the Controller which converts it to the 0 to + 10V feedback signal.

6.4 SERVOVALVE

Aim: To verify correct Servovalve operation before closing the loop.

- A suitable driver is needed to independently drive the control valve. This can be a ‘battery box’ or power supply driving a potentiometer to provide a manually adjustable valve signal.
- Moog Valve Checkers are available for MFB and EFB valves.
- Remove the connector and fit the connector from the Valve Checker.



6.4.1 Servovalve operation

- Verify correct Servovalve operation by moving the CONTROL KNOB through the middle mark; say, up to ± half the available angle thus driving the actuator backwards and forwards.
- Confirm that motion clearly follows the KNOB movement. This is best done by observing the actuator slowing, stopping and reversing. Any problem with the Servovalve normally shows up in this region.

TROUBLE-SHOOTING: Closed loop problems will exist if the Servovalve can not be manually controlled to provide smooth low speed control of the cylinder. That is, good automatic closed-loop control is not possible unless an operator can manually do what the controller must do; namely, smoothly and repeatably bring the cylinder to rest and turn it around and smoothly control it in the other direction. A finger placed on the rod near the wiper at the same time as the drive signal is slowly reversed will help this judgement.

The MECHANICAL NULL setting of a new Servovalve as supplied is unlikely to be exactly suited to your application. The MFB Servovalve null is best checked at the actuator when the oil running temperature is reached and the correct pressure is set. At the actuator, remove the connector from the Servovalve and observe the creep speed. A creep speed of 1 to 2% maximum speed is acceptable. NOTE: A Servovalve is used to finely position and must have near zero overlap/underlap spool cut; a so-called axis cut. Without position feedback, that is during this testing phase, it is in open loop mode which means that it is not possible to hold the actuator completely stationary. In other words, it is normal that the load creeps and it is an exception when it is stationary.

6.4.2 Servovalve Polarity

Connect the servoamplifier valve cable to the servovalve and disconnect the feedback signal on pin 3.

Input the correct polarity command and verify that the actuator moves in the correct direction. Note that for unipolar (eg. 0 to 10V) command signals, it may be difficult to drive the valve in both directions. The ideal is to have an offset equivalent to 50% of the command level but of the other polarity to allow the actuator to be driven equally fast in both directions. Alternatively, CCW rotation of the **zero** pot will oppose a positive voltage command while CW rotation will oppose a negative voltage command. Retune the **zero** pot later in 6.7, Final Transducer trim with actual command.

If the direction is incorrect, reverse the Servovalve connections at the card frame terminal strip.

For a Mechanical Feedback (MFB) Servovalve, these connections are at pins 13 and 15.

An Electrical Feedback valve (EFB) has two inputs of different polarity, typically pins D and E. Locate the wires that connect the valve connector pins D and E and swap them at the terminal strip. One will go to pin 13, the other to ground. Remember that the unused input pin must always be grounded.

6.5 TRANSDUCER

Aim: To initially SCALE and ZERO the transducer controller (not the servoamplifier) in open loop mode using the Moog Valve Checker to drive the cylinder from end to end.

Normally it is easier to drive it in open loop but the same effect can be achieved if the effective command signal can be increased to overdrive the cylinder hard onto its end stops.

The end stops are preferred reference points because they are solid, repeatable and not subject to individual interpretation.

A fine adjustment will be still necessary but this is only possible after the **gain** P2 is adjusted in section 7.6 and using the actual external position command. See section 6.7.

The Feedback input is typically pin 3, ground = pin 22.
The front panel 2 mm **Vin3** Testpoint carries the position feedback voltage.

In the following, we use an example of a " 0 to 10V " transducer output.

6.5.1 ZERO

- Retract the cylinder fully with the VALVE CHECKER.
- Adjust the TRANSDUCER CONTROLLER ZERO to give 0 ± 0.005 V.

6.5.2 SPAN / SCALE

- Extend the cylinder fully with the VALVE CHECKER.
- Adjust the TRANSDUCER CONTROLLER SPAN / SCALE to give 10 ± 0.010 V.

Repeating: The final transducer fine adjustment is described in 6.7 and can only take place after the **gain** P2 is adjusted in 6.6 and the actual external position command is available. This final trim takes care of mV. level offsets.

6.6 CLOSED LOOP OPTIMISATION

Aim: To tune or optimise the position loop using either of the following inputs

- a step change in the command signal (at pins 3 or 9) or
- a step valve drive disturbance signal at pin 19.
  Note:
  - A step valve disturbance allows easy measurement of Proportional Band and thus estimation of accuracy.

and then judging the response of either by monitoring either:

- the change in a transducer signal or (see section 6.6.2)
- the change in the error or valve drive signal. (see section 6.6.3)

6.6.1 Initial set-up

PID Servoamplifier initial settings

1. For the controller to function, one of the PID links must be selected. eg select P link = ON, ie. I and D = OFF.
2. Reduce P2 gain to a minimum, ie. fully CCW.

Hydraulic and mechanical initial settings

1. Reduce hydraulic pressure to a safe level.
2. Disconnect the load if the possibility of damage exists.

Input Options / Choices

1. PLC or signal generator to produce a single step change or a repetitive step change.
2. A 1k to 10k single turn potentiometer with a switch to provide a variable input step.
3. Wire from an input terminal and connect by hand to one of the supply pins.

Response Monitoring Choices

1. An oscilloscope can be used to advantage to monitor either Isv (proportional to the error with a P-Controller) or the transducer response and ensure optimum tuning. See section 6.7.2
2. The Isv LEDs enabling monitoring of the error response. See 6.7

6.6.2 Monitor Transducer Response

–

6.6.3 Monitor Error or Valve drive Isv Response

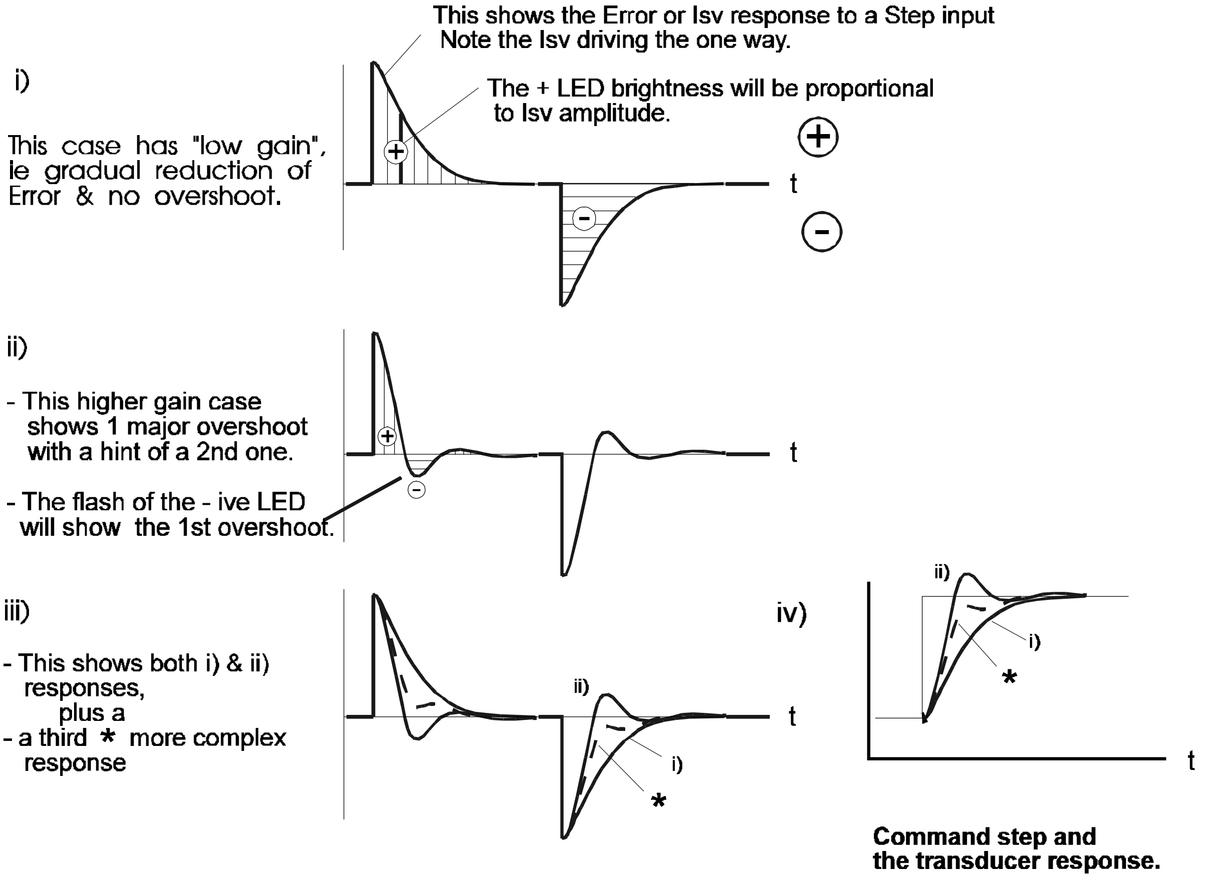
- Refer to the graphed responses I) and ii) below.

Safe reduced hydraulic pressure and load inertia

- Advantages of Monitoring Isv: Because the error is symmetrical around zero, it is simpler to observe on the oscilloscope. It will not change position and the same scale can be used independent of transducer output. When monitoring the Transducer response, a magnified view can normally only be obtained when the transducer signal is close to zero.
- Pin 12 gives the output of the Summing Amplifier, ie the error signal. Alternatively for a P-configured amplifier, Isv provides a more convenient Testpoint.
- Connect the disturbance input to pin 19. With the hydraulics turned off, verify that the Isv Disturbance is between 20 & 50% of the rated valve current. It is generally recommended to start off with a small value. CAUTION: It is not recommended to continuously drive the valve without hydraulic pressure.
- Generate the 'STEP' Disturbance and hold it long enough for the system to settle. This input produces a change or disturbance in the valve drive signal Isv & the actuator position changes as the closed loop tries to cancel the disturbance. Release the push button and the actuator comes back to the original position.
- Observing the actuator or the Isv LEDs will indicate how well tuned the position control loop is. The aim is to get the fastest response with minimum position overshoot. This will give the best accuracy with the best response.
- For low **gain** (no overshoot) only one of the Isv LEDs will come on as the system drives towards the new set point. See i) of the graphed responses. For example, when generating a STEP, one Isv LED is lit, when the STEP is removed, the other Isv LED is lit. As the system reaches the new position the Servovalve current Isv reduces and the LED fades.
- Turning the P2 pot clockwise (CW) increases the **P gain** and the system may *overshoot*. This means that the actuator goes first beyond the required end position and then comes back.

The opposite Isv drive LED will come on momentarily as the system drives back to the required end position. This short flash of the of the opposite Isv drive LED is a good means of detecting overshoot. See graphed response i).

– Typically the **gain** POT is increased until there is hint of a slight overshoot.



Error or Control Valve Drive Isv response to either a step disturbance or a step command change

Command step and the transducer response.

Note correspondence between the error and the transducer signal for a P-Controller

Full supply pressure and load inertia

– When it is verified that the gain range provides a stable response and everything is working correctly, restore the hydraulic pressure to the rated value. When the load inertia is restored, the above tuning process will need to be repeated. Again start cautiously with a low **gain** value.

low gain range

– If an overshoot is not obtained with the **gain** fully clockwise, then the gain range of the amplifier is insufficient. Increase the gain range by increasing resistor R20. This is mounted on soldering posts and can easily be changed in the field. See Section 5.2 / 5.3 for a component location drawing.

high gain range or instability

– If an overshoot or instability is always present, it may mean that the gain range is too high. Hence lower the value of R20. If lowering the gain does not remove the instability than look for other causes. For example: electrical noise, a malfunctioning valve or play or stick-slip in the drive chain.

*importance of higher **gain***

– It will be seen that the higher the gain, the smaller the distance the STEP Isv disturbance' is able to 'disturb' the position of the cylinder. This higher gain works to suppress any system disturbances such as valve errors or load disturbances. See 6.8.3.
  - The higher the **gain**, the higher the accuracy.

- The higher the **gain,** the higher the response. Do **not** lower the **gain** in order to slow the system down. Doing so will degrade the position accuracy. Instead slow down the position command. Do this by limiting the velocity of the command, for example with the Ramp circuit.

– If the **gain** is set too high, the initial overshoot can turn into continuous oscillations. Reduce the **gain** to avoid damage to the system.

6.6.4 Proportional Band and Achievable Static accuracy

Assume a 20% Isv disturbance signal has been selected.

The 20% Isv disturbance causes the cylinder to move and the transducer feeds back an opposite signal to balance the disturbance. How much influence the valve disturbance has decreases as the electronic **gain** increases. This is because a smaller cylinder position change is amplified by a higher gain to counter the 20% Isv disturbance.

How far the cylinder moves for 100% Isv disturbance is called the Proportional Band. It is called the Proportional Band because within this band, the Servovalve drive signal and hence the speed is proportional to the position error.

Clearly the Proportional Band will be five times that observed with the 20% Isv disturbance.

Aside: For position errors larger than the Proportional Band, the valve drive signal is at maximum and there is no further change in velocity. The system is momentarily no longer in closed loop control. Closed loop control resumes once the position catches up, typically when the Command stops and the Proportional Band is re-entered. Only if constant speed or constant cycle time is required is this a problem, in which case the normal solution is to ramp the position command.

Long Term Accuracy with a Proportional Controller

The accuracy of a position loop is based upon the Isv needed to overcome all possible disturbances, for example, worst case valve drift and load changes. Typically ± 5% Isv or ± 5% proportional band is used as a measure of accuracy for axis-cut valves, to cover all such contingencies.

Therefore the achievable Long Term Accuracy is 5% of the Proportional Band which is clearly 1/4 of the movement resulting from the 20% Isv Disturbance.

e.g. 20 % Isv Disturbance produces a 1 mm movement, then 5% = 0.25 mm
i.e. Long Term Accuracy = ± 0.25 mm

Short Term Accuracy with a Proportional Controller

Short Term Accuracy, i.e. repeatability from cycle to cycle, is much smaller and can be 1/4 to 1/10 of the Long Term Accuracy. Short Term Accuracy is set by the valve threshold and pressure gain together with load changes from cycle to cycle.

In the above example, Short Term Accuracy is < ± 0.06 mm

6.6.5 Lead Compensation

A LEAD is a phase advance circuit used to compensate for lags in other components. It is also called a DERIVATIVE TERM and is the ‘D’ in a P-I-D Controller. This compensation is normally of benefit only if the Servovalve is the lowest natural frequency component in the Position Control System. It typically allows up to a 20 to 40% increase in gain which will improve static accuracy, reduce the following error and improve the dynamic response.

Method

– Refer to section 5.3.2.3 for a graphical presentation of the effect of P6 and P8.

– Initially set P6 fully counter-clockwise (CCW) and P8 fully clockwise (CW) so that the D is in-effective. Change the D- link to ON.

– As above, press the ‘STEP’ push-button to observe the response. Increase the gain until normally unacceptable overshoot results.

– Now start to turn P6 CW and note any effect on the overshoot. Note the pots have 15 turns travel.

– If there is no effect, or more is required, start to rotate P8 CCW.

– Stop if the valve starts to buzz or both the Isv LEDs glow. This signifies either high frequency closed loop instability or excess amplification of electrical noise. Both present a limit to how big the LEAD can be.

– If no improvement is apparent, select the ‘D = OFF” link.

6.6.6 Lag Compensation

A LAG is a phase retarding circuit used in this case to reduce the peaks of lowly damped “oil spring - system mass” natural frequencies OR purely as a Low Pass filter to remove electrical noise from a signal.

Method

– Press the ‘STEP’ push-button to observe the response. Increase the gain until the system overshoots 2 or 3 times.

– If this oscillation frequency is the “oil spring - system mass” natural frequency rather than the well damped control valve 90 degree frequency, then Lag Damping can be used. On the other hand, Lead Compensation could help if the frequency was that of the control valve 90 degree phase lag frequency.

– Measure the frequency ‘f’ in Hz (cycles/sec) of the oscillation.

– Chose a break point frequency between ‘f / 2’ and ‘f / 4’ and select C3 to achieve this.

Break point frequency = 1 / (2 π R C).

R20 ⇩	C3 ⇩		Time constant	Break point frequency
100K	10 nF	➪	1 ms	150 Hz
100K	100 nF	➪	10 ms	15 Hz

– Fit C3 & retry with the ‘STEP’ push-button. The response should now have less over-shoot.

For use with noisy signals

– This roll-off method can also be used to remove or reduce valve chatter caused by amplification of noise (from say a transducer) at high **gain** settings.

– If the valve dynamics are lower than that of the “oil spring - system mass” natural frequency, be careful of choosing a roll-off frequency that is too low and degrades the system response.

– Note that valve chatter can lead to premature valve wear.

6.7 FINAL TRANSDUCER TRIM WITH ACTUAL COMMAND

The following assumes that + 10V Command = extended, ie., - Isv LED = **extend.** If - 10V = retracted, then + Isv LED will = **extend.**

– Supply the final Setpoint or Command signal and fine trim ZERO and SPAN as follows.
– Use either the adjustments on the transducer card of the command generator.
– Also use the cylinder end-stops as a reliable repeatable reference.
– If scaling in mm or inches is required, measure the cylinder stroke to the same accuracy as the accuracy of the scaling required.

6.7.1 ZERO

– Supply full retract command, i.e. 0V.

– Trim the transducer conditioning card zero until the **+ Isv** (**retract)** LED just glows. This indicates that the cylinder has retracted hard up against its end stop.

– For critical set-up, use the test point **Isv** to set an actual Isv value rather than judge the glow of the LED. Set the voltage to between 6 & 20% Isv.

– If this test is repeated at different times, it will be found that this value may change slightly. This is typically due to drift in the position transducer output and perhaps the command signal.

6.7.2 SPAN

- Supply full extend command, i.e. + 10V
- Trim the transducer conditioning card span until the **- Isv (extend)** LED just glows. This indicates that the cylinder has extended hard up against the end.
- For critical set-up, use the test point **Isv** to set an actual Isv value rather than judge the glow of the LED. Set the voltage to between 6 & 20% Isv.
- Similarly, this value may vary slightly over time due to drift in the position transducer output and perhaps the command signal.

6.8 SERVO VALVE ADJUSTMENTS

Null adjustment

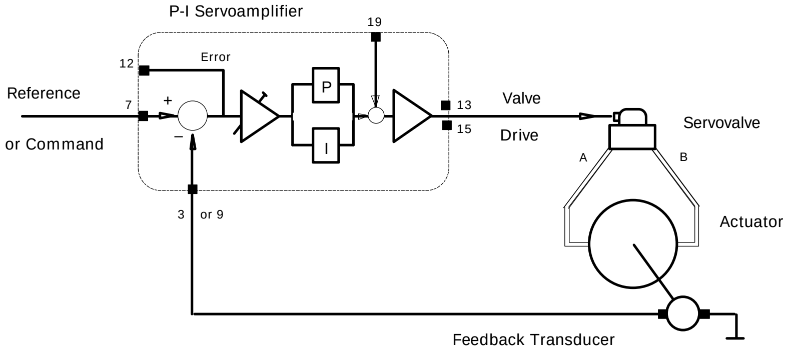
Aim: To adjust the null or zero position of the valve until there is no cylinder movement for zero input. Note that the Servovalve null can change by up to 1 to 2% depending upon the oil temperature. Hence you cannot expect the cylinder to remain stationary when operating conditions change.

MFB valves
It is best to completely remove the connector at the valve to easily and accurately obtain zero input. After referring to the appropriate service manual, trim the mechanical null so that the creep speed is less than, say, 1 to 2% maximum speed.

EFB valves
It is not possible to remove the connector as with the MFB valves because this would also remove the electrical power that the valve needs for its electronics. Instead ensure 0V command signal and adjust the trim potentiometer to obtain less than 1 to 2% of maximum speed.

7 VELOCITY LOOP COMMISSIONING

7.1 CLOSED LOOP NOTES



Typical Velocity Loop

A Velocity loop is a control system that uses a velocity transducer to measure and feedback velocity.

Generally the term Velocity Loop is not used for a position loop that achieves velocity control by ramping the position command. This is a position loop with a ramped position command. See Position Loop section for a description.

Note the need to clamp the I-Integrator if the loop is inactive or zero velocity is called up. See section 4.3.5.

A P-I Controller is assumed as the normal structure. See section 9.1.2.

7.2 COMMISSIONING SUMMARY & CHECKLIST

The check list below is a summary of the commissioning notes in the following pages.

		SECTION
SERVOVALVE (see also 6.4)		**7.3**
– Use a Manual Valve Checker to drive the valve	☐	
– Verify functioning of valve	☐	
– Verify valve polarity	☐	
TRANSDUCER		**7.4**
– Drive the control valve open loop		
– POLARITY	☐	7.4.2
– ZERO = 0 ± 0.005 V	☐	7.4.3
– SCALE = 10 ± 0.01 V	☐	7.4.4
CLOSED LOOP OPTIMISATION		**7.5**
– Initial set-up	☐	7.5.1
– P gain	☐	7.5.2
– I + P gain	☐	7.5.3
FINAL TRANSDUCER TRIM		**7.6**
– Retrim transducer to suit external position command	☐	
SERVOVALVE ADJUSTMENTS		**7.7**
– Less critical if an Integrating controller is used.	☐	

7.3 SERVOVALVE FUNCTION AND POLARITY

Aim: To verify correct Servovalve operation before closing the loop.

7.3.1 Servovalve Operation

– See section 6.4.1

7.3.2 Servovalve Polarity

– See section 6.4.2 for more detail of the following.
– Configure servoamplifier as a "P"
– Remove the feedback signal.
– Input the Command signal and verify that the direction of the motion is correct.
– If required, reverse the electrical signal to the servovalve.

7.4 TRANSDUCER CHECK

– Use either the valve checker as per 6.4.1 or drive the control valve open loop with the command and the controller configured as just **P**.

7.4.1 Polarity

– Check that the output polarity is opposite to the Command polarity.
– If the device does not allow inversion of the signal, consider using the inverting amplifier available on the G122-202.

7.4.2 Zero

– Tachometer: A tachometer does not require a zero adjustment
– If a zero adjustment is provided, turn off the hydraulics to establish zero velocity.

7.4.3 Scale

– Often an independent velocity measuring device is useful to calibrate and scale the velocity transducer.
– IF this is done in close loop operation with pin 9 as the input, increase the speed by turning P9 clockwise.

7.5 CLOSED LOOP OPTIMISATION of P - I CONTROLLER

Aim: highest P-I gain = best performance, namely best command and disturbance response, best accuracy. The **gain** is set by optimising the response to a step input.

Tune or optimise the velocity loop using either of the following inputs:

- a STEP change in the command signal on pins 3, 9 or 11 (with Z2 loaded)
- a STEP valve drive disturbance signal on pin 19. (see section 7.5.2)

Judge the response of either by monitoring either:

- the change in a transducer signal or (see section 7.5.2)
- the change in the error on pin 12. (this mirrors graphed response in 6.6.3)

7.5.1 Initial set-up

PID Servoamplifier initial settings

1. Select P link = ON, i.e. with D = OFF and I = OFF or clamped.
2. Reduce P2 gain to a minimum, i.e. fully CCW.
3. Reduce P5, the I-gain to a minimum, (i.e. turned fully CCW) in preparation. Note that it is better if the 'I' part is clamped to zero rather than just selected OFF. This will remove any start-up glitch when the 'I' is turned on later.

Hydraulic and mechanical initial settings

1. Reduce hydraulic pressure to a safe level.
2. Disconnect the load if the possibility of damage exists.

Input Options / Choices

1. PLC or signal generator to produce a single step change or a repetitive step change.
2. A 1k to 10k single turn potentiometer with a switch to provide a variable input step. Wire one end if the pot to a 15V supply pin and the other to ground. The wiper can go to pin 3 or 9 as a Command input or pin 19 as a Disturbance input. It could also go in via the front panel Testpoints.
3. Take a piece of wire from an input terminal and connect by hand to one of the supply pins. Use pins 3 or 9. Pin 3 will require either changing R1 or adding a resistor externally to limit

the size of the STEP. If pin 9 is available, pot P9 provides an adjustable ∆Command suitable for the STEP.

Note that it may be convenient to set a base speed with an input to pin 7 via the low pass filter and use another pin for the smaller STEP disturbance. The low pass filter on pin 7 rules it out for the dynamic input.

Response Monitoring Choices

1. An oscilloscope can be used to advantage to monitor the transducer response to ensure optimum tuning. A digital storage oscilloscope is preferred with a roll mode or a slow (0.1 to 2 sec) time base.
2. The Isv Drive LEDs are not effective because Isv does not come back to zero.

7.5.2 Method

Command

- Set the speed command or setpoint for mid range speed. The actual command value required here will be much higher than that needed later with the 'I' fitted.
- Input a STEP speed change large enough to cause a change in Isv of 20 to 50%.
- Use pin 19 if an Isv disturbance is required.
- During the following set-up, vary the speed over the operating range to check the behaviour and if necessary choose another more critical speed for optimising if the response varies significantly.

"P" Controller

- Increase 'P' by turning the **gain** pot P2 slowly clockwise.
- Observe the response for the start of overshoot.
- Back off the **gain** until one overshoot is present.
- This sets the optimum 'P' gain.

Note that in some cases it may not be possible to obtain a response without any oscillatory behaviour using a P controller.

Option 1:

Reduce R20 from 100k to 22k and recheck the response. This lowers the minimum **gain** of the summing amplifier and hence the closed loop response.

Option 2:

It may be possible to maintain the gain but reduce some of the oscillatory behaviour by rolling off the frequency response of the summing amplifier A1:A. First increase the **gain** until the system goes unstable or near unstable. Capture this on the storage oscilloscope and measure the frequency 'f'. Choose a break point frequency between 'f / 2' and 'f / 4' and select C3 to achieve this.

Note; Break point frequency = 1 / (2 π R C), for example:

R20 ⇩	C3 ⇩	Time constant	Break point frequency
100K	10 nF ➪	1 ms	~ 150 Hz
100K	100 nF ➪	10 ms	~ 15 Hz

- Recheck the response. The aim is to reduce the overshoot without significantly reducing the response time.

Aside:

- This roll-off method can also be used to remove or reduce valve chatter caused by amplification of noise (from say a transducer) at high **gain** settings.
- Note that valve chatter can lead to premature valve wear.

Integral Controller with P

- Enable "I" by de-energising the clamp relay or if the "I" link was OFF, power down, remove the card and select the 'I' link = ON.
- Reduce the command amplitude to obtain the same speed that you had before.
- Input a step change large enough to cause a change in Isv of 10 to 50%.
  Alternatively use pin 19 for 25% Isv disturbance.

- If response to a change in command is important, optimise with a step change in the speed command to either pins 9 or 3 (or load Z2 & use pin 11).
- If response to a process disturbance is important, optimise with a step change in Isv using pin 19.

- Increase 'I' by turning pot P5 clockwise and observe the response.
- Continue to increase P5 CW until a lower frequency oscillation results. Typically reduce P5 back until just the hint of one overshoot is present.

- Note the "I" and the "D" work in two widely separate frequency domains, I ≡ low frequency and D ≡ high frequency. This allows them to be separately tuned.

Integral Controller with P and D

- refer to 5.3.2.3 and 7.6.5

7.5.3 Final transducer trim with actual command

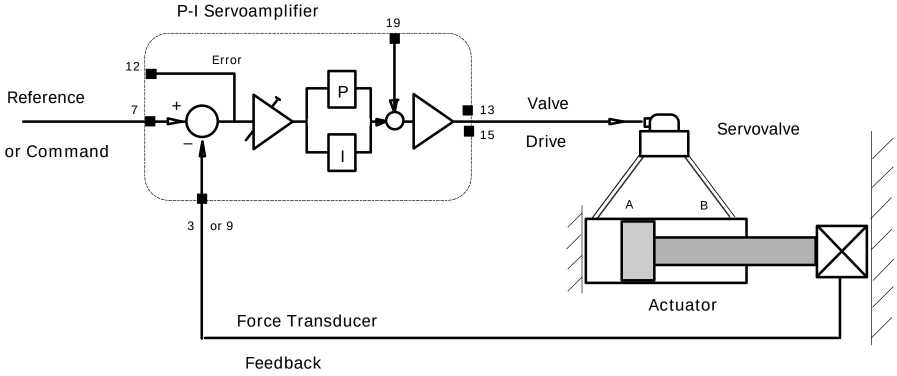
- Set two velocities, one very low and one very high. Recheck SCALE and ZERO. It is not possible to set & maintain zero velocity with the closed loop control.
- Only the operational amplifier offsets will need to be trimmed out and this will have little effect on the output level.

7.5.4 Servovalve Null adjustment

- The Integrator will cancel out the effect of any Servovalve offset so that null adjustment is less critical.
- Many control valves used for velocity loops will have overlap (dead-zone around null) which makes null adjustment non-critical.
- An axis-cut valve will normally have auxiliary valves to "lock" motion when true zero velocity is required.
- Nevertheless, a control valve offset may influence start-up smoothness. Therefore with zero valve drive, adjust the mechanical null until minimum creep is obtained.

8 PRESSURE / FORCE LOOP COMMISSIONING

8.1 CLOSED LOOP NOTES



Typical Force Loop

A Force or Pressure loop is a control system that uses a transducer to measure and feedback force or pressure.

A force control is shown but one or two pressure transducers can be use to derive a force signal. The control adjustments are similar.

A P-I Controller is assumed as the normal structure, see also 9.1.3.

8.2 COMMISSIONING SUMMARY & CHECKLIST

The check list below is a summary of the commissioning notes in the following pages.

		SECTION
SERVOVALVE		**8.3**
– Use a Manual Valve Checker to the drive valve	☐	
– Verify functioning of valve	☐	
– Verify valve polarity	☐	
TRANSDUCER		**8.4**
– POLARITY	☐	
– ZERO = 0 ± .005 V	☐	
– SCALE = 10 ± .010 V	☐	
CLOSED LOOP OPTIMISATION		**8.5**
– Initial set-up	☐	8.5.1
– P gain	☐	8.5.2
– I + P gain	☐	8.5.2
FINAL TRANSDUCER TRIM		**8.6**
– Retrim transducer to suit external position command	☐	
SERVOVALVE ADJUSTMENTS		**8.7**
– Less critical if an Integrating controller is used.	☐	

8.3 SERVOVALVE FUNCTION AND POLARITY

Aim: To verify correct Servovalve operation before closing the loop.

– See section 6.3

8.4 TRANSDUCER CHECK

– Use either the valve checker as per 6.4.1 or drive the control valve open loop with the command and the controller configured with just **P**.

8.4.1 Polarity

– Check that the output polarity is opposite to the Command polarity.
– If the device does not allow inversion of the signal, consider using the inverting amplifier available on the G122-202.

8.4.2 Zero

– If a zero adjustment is provided, turn off the hydraulics to establish zero pressure and trim the output.
– If no trim is provided, use P1 zero pot as per 8.5.3.

8.4.3 Scale

– A pressure gauge can be used to calibrate or check the pressure transducer.

8.5 CLOSED LOOP OPTIMISATION of P - I CONTROLLER

Aim: highest P-I gain = best performance, namely best command and disturbance response, best accuracy. The **gain** is set by optimising the response to a step input

Tune or optimise the force/pressure loop using either of the following inputs:

- a step change in the command signal on pins 3, 9 or 11 (with Z2 loaded).
- a step valve drive disturbance signal (on pin 19).

Judge the response of either by monitoring either:

- the change in a transducer signal or
- the change in the error on pin 12

8.5.1 Initial set-up

PID Servoamplifier initial settings

1. Select P link = ON, i.e. with D = OFF and I = OFF or clamped.
2. Reduce P2 gain to a minimum, i.e. fully CCW
3. Reduce P5, the I-gain to a minimum, i.e. turned fully CCW, in preparation. Further, it is better if the 'I' part is clamped to zero. This will remove any start-up glitch when the 'I' is turned on later.

Hydraulic and mechanical initial settings

1. Reduce hydraulic pressure to a safe level.

Input Options / Choices

1. PLC or signal generator to produce a single step change or a repetitive step change of variable amplitude.
2. A 1k to 10k single turn potentiometer with a switch to provide a variable input step. Wire one end if the pot to a 15V supply pin and the other to ground. The wiper can go to pin 3 or 9 as a Command input or pin 19 as a Disturbance input. It could also go in via the front panel Testpoints.
3. The minimum required is a piece of wire from an input terminal held by hand to one of the supply pins. Switch by making and braking contact. Use pins 3, 9 or 19. Pin 9 if available is convenient because P9 allows scaling of this ∆Command for the STEP. Pin 3 or 19 will require either changing the input resistor or adding a resistor externally to limit the size of the STEP.

Response Monitoring Choices

1. An oscilloscope can be used to advantage to monitor the transducer response to ensure optimum tuning. A digital storage Oscilloscope is preferred with a roll mode or a slow (0.1 to 2 sec) time base .
2. The Isv Drive LEDs are not effective because Isv does not come back to zero.

8.5.2 Method

Command

– Set the command to produce a pressure / force of about 1/2 maximum. Note with a "P" only amplifier, that a pressure lower than the COMMAND PRESSURE will result. Do not try to correct this with the COMMAND SPAN or ZERO pot at this point if " **I** " is going to be used later.
– Make a 10% step change in COMMAND PRESSURE. Reduce this level if the control valve drive (Test-point Isv) exceeds the maximum rated current. That is, the operation goes outside the linear or proportional range. In that case the optimisation method is not valid.

"P" Controller

– Increase the Proportional part of the controller action, i.e. increase the 'P' by turning the **gain** pot P2 slowly clockwise. The pot has 15 turns and the transparent housing allows the position of the wiper to be established.
– Observe the pressure feedback response for the start of overshoot.
– Back off the **gain** until one overshoot is present.
– This sets the optimum 'P' gain.

"Control" Aside: the high frequency observed corresponds usually to the frequency at which the phase lag of the control valve is 90 degrees.

– Pressure Loops can be very complex with line resonances disturbing the response. Having the pressure transducer mounted as close as possible to the control valve will minimise this problem. (Force loops do not have this complication.) These resonances lead to oscillations at frequencies (typically lower than that of the 90 degree phase frequency of the control valve). The gain is thus limited and hence response and accuracy is similarly limited.
  - If this frequency < valve 90 degree frequency, it is likely that a low pass filter will help. Chose C3 to roll off A1:A at a frequency 1/2 to 1/4 of the oscillation frequency. See also 8.4.2 option 2 for more detail.
  - If this frequency > valve 90 degree frequency, it is likely that "D" will help.

Integral Gain with P

– Enable "I" by de-energising the clamp relay or if the "I" link was OFF, power down, remove card and select 'I' link = ON.

– Set the command to equal 1/2 the supply pressure. The Integrating action of the "I" controller will now ensure that the correct pressure will be reached, i.e. if the COMMAND SCALE & ZERO have been adjusted correctly.

– Make a 10% step change in COMMAND PRESSURE.

– Turn 'I' pot P5 slowly clockwise and observe the response.

– Continue to increase P5 CW until a lower frequency oscillation results. Reduce P5 back until one overshoot is present.

– Finally juggle both **gain** and **P5** to see if a performance improvement can be obtained.

8.5.3 Final transducer trim with actual command

– Set two pressures, one very low and one very high. Recheck SCALE and ZERO. Do not try to control zero pressure with the closed loop control.

8.5.4 Servovalve Null adjustment

– The Integrator will cancel out the effect of any Servovalve offset so that null adjustment is less critical.

9 APPENDIX

9.1 BASIC CONTROL NOTES

9.1.1 POSITION LOOP

Minimum and Normal Standard Structure = P Controller

- The control valve plus actuator has an integrating action. That is, the output position grows with time, ie., integrates for a constant control valve input.
- Using a "P" Controller, the resulting system (Type 1) has a zero steady-state error to a constant input provided the hydraulic integrator is a perfect integrator.
- Position loops using just a "P" Controller are simplest to adjust and to troubleshoot. They also give a good accuracy / settling time trade-off.

Extended Structure = P-D Controller

- A "D" component can be fruitfully used to improve the dynamic performance of the loop.
- It is only of value if the underdamped hydraulic-mass natural frequency is higher than the 90 degree phase lag frequency of the control valve. Trial and error will normally indicate if the D component is of value.

Extended Structure = P-I-D Controller

- The addition of the Integrating "I" component can be used to over-come the imperfections of the hydraulic integrator, namely the drop-off of DC-gain due to internal leakage.
- The I - Controller takes more time than the P - Controller to settle. Hence the increased accuracy is obtained only with longer settling times.
- Unfortunately, it is difficult to tune and manage the Integrator in a position loop without hunting and overshoot. Because of this and the fact that high accuracies can be obtained normally anyway with 'stiff' hydraulic control, it is not often used.

9.1.2 VELOCITY LOOP

Minimum Structure = I Controller

- The control valve plus actuator has a proportional action. That is, the output velocity is proportional to the control valve input.
- To make up for the missing hydraulic integrator in the Position Loop, an electronic integrator is added. This electronic integrator is closer to an ideal integrator than the hydraulic one. The result is a control loop with the same configuration as the Position Loop with a P-Controller, ie., Type 1 system meaning zero steady-state error for a constant input.

Normal Structure = P-I Controller

- The addition of the "P" is the equivalent of the -D- in the position loop. It is similarly only of value if the underdamped hydraulic-mass natural frequency is higher than the 90 degree phase lag frequency of the control valve. Often though this is less clear cut with a hydraulic motor where the internal leakage does increase damping far in excess of that of a hydraulic cylinder.
- Many Velocity Control loops use the P-I configuration.
- If the Velocity loop is turned off or zero Velocity is called for, the Integrator must be "shorted out" to prevent drift.

Extended Structure = P-I-D Controller

- Similarly the "D" can be of value if the system damping allows it.

9.1.3 PRESSURE or FORCE LOOP

Minimum Structure = P Controller

– The control valve plus actuator volume compliance has an integrating action. That is, the output pressure grows at a constant rate with a constant control valve input.

– The basic controller will be a P-Controller as with the position loop. It differs, though, in that the internal leakage has more effect on the steady-state pressure error than on the steady-state position error. See P-I Controller.

Normal Structure = P-I Controller

– The electronic Integrating action compensates for the leakage in the control valve around null and reduces the steady state pressure error to zero (within the limits of the electronic Integrator).

– Most Pressure or Force Control loops use the P-I configuration.

– If the loop is turned off or if zero pressure or force is called for, the Integrator must be “disabled” or shorted to prevent drift.

Extended Structure = P-I-D Controller

– In the case of a pressure loop, the “D” can be of substantial value as mostly the control valve dynamics limit the response rather than the lowly damped “oil spring-system mass” natural frequency. Thus the phase lead nature of the “D” can compensate for the phase lag of the valve.

NOTES: