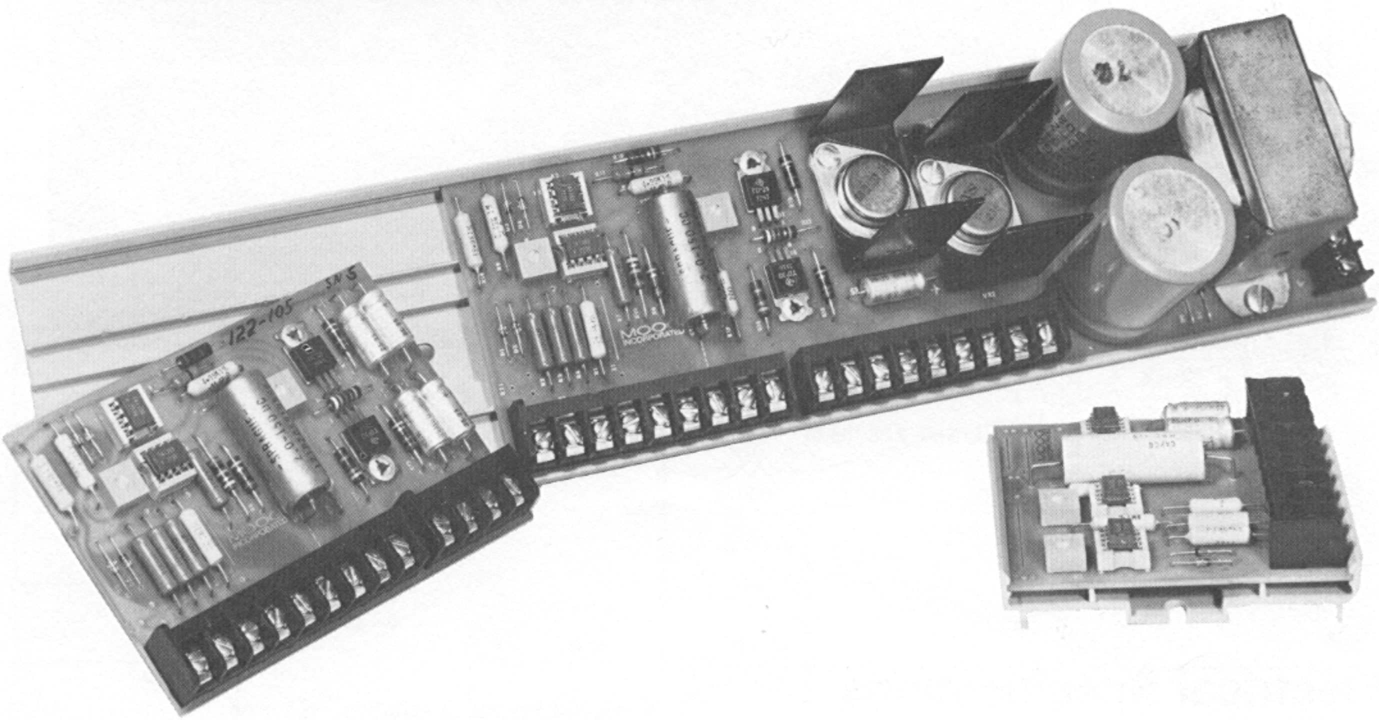
MOOG® Snap Trac Servo Electronics



Moog's Snap Trac Servo Electronics provide a low cost solution to the need for high performance servo control for manufacturers of industrial vehicles and industrial equipment. These modular circuit cards simplify selection and packaging for various control systems. This modular approach also provides growth potential in that additional modules are easily added-on.

Snap Trac circuit boards are growing in popularity as a low cost and convenient packaging technique for industrial electronics. Snap Trac mounting facilitates installation, maintenance and replacement of electrical components. All components share the environmental protection of a common electrical equipment cabinet, and the number of interconnecting cables and connectors is minimized.

SERVOCONTROLLER FEATURES

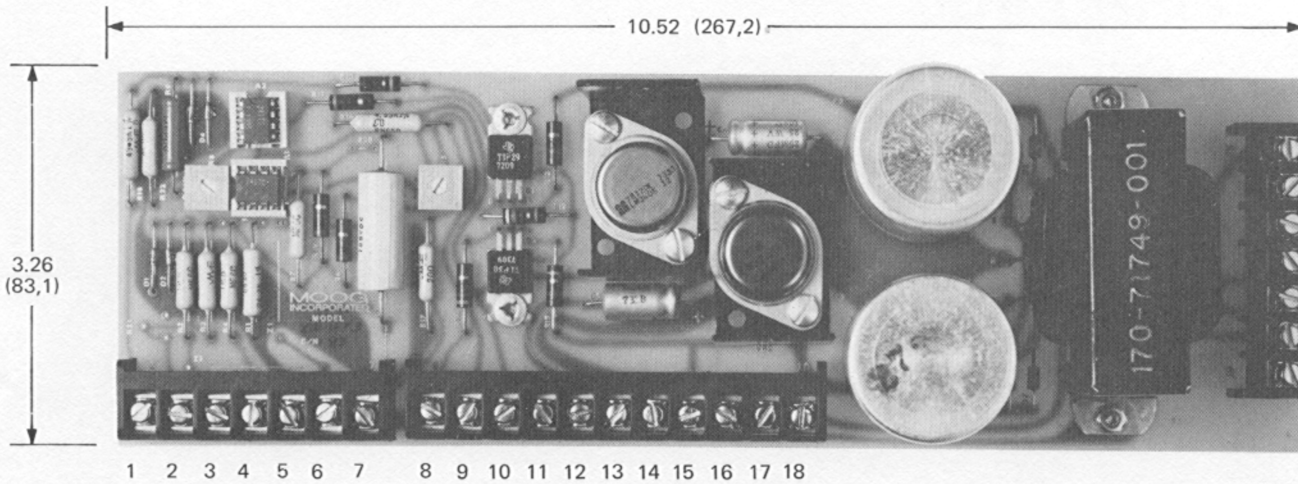
- operates with standard 115/230 VAC 50/60 Hz power
- add-on servoamplifiers share same power supply
- regulated excitation for feedback transducers
- provisions for multiple signal inputs and feedbacks
- summing resistors can easily be changed for scaling signals
- circuit can be modified for proportional or integral control
- convenient servoloop gain and bias adjustments

Model 121-103 Servocontroller

FOR 115/230 vac, 50 to 60 Hz POWER

This Snap Trac circuit board contains a complete dc servoamplifier together with an ac to dc rectifier and voltage regulators. The internal power supply has capacity for two or three Model 122-105 Servoamplifiers depending upon the power consumption utilized for other system components.

The servoamplifier portion of the Model 121-103 is identical to the Model 122-105.



MAXIMUM COMPONENT HEIGHT 2.35 (58,5)

Electrical Specifications

Servoamplifier

- inputs
- output
- gain
- drift
- frequency response

} Same as Model 122-105 (see page 4)

Electrical Power Required

- 105-125 vrms, or 210-250 vrms, single phase, 50 to 60 Hz, approximately 10 va at maximum capacity
  - for 115 vac power, jumper terminals 19, 20 and terminals 24, 25
  - for 230 vac power, jumper terminals 20, 24

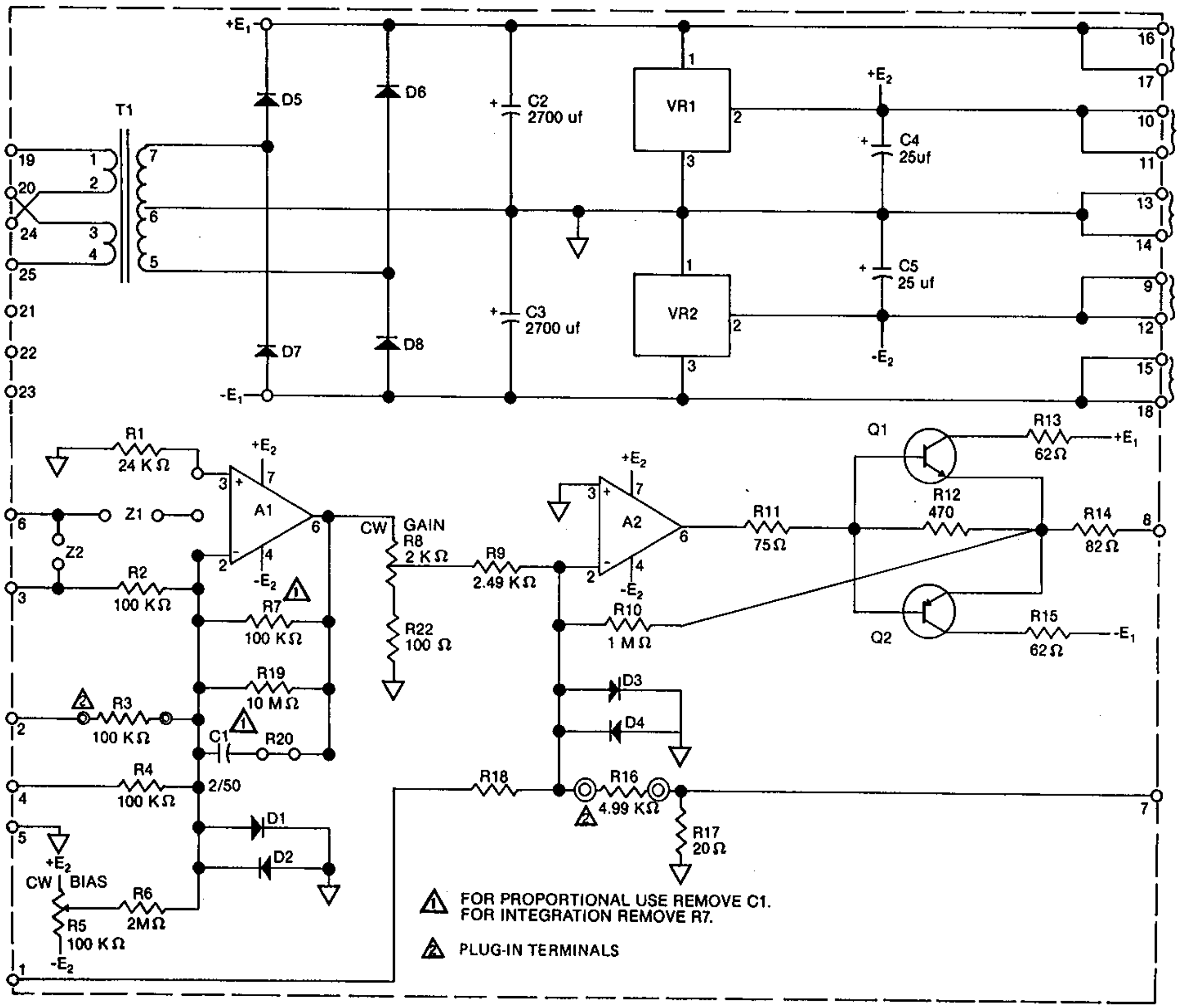
External Power Available

- ±15 to ±20 vdc, unregulated, 3-wire at ±250 madc
  and
  ±12.0 vdc, regulated, 3-wire at ±150 madc
  - ±12.0 vdc regulated current drain must be included in unregulated current capacity
  - ±12.0 vdc regulated supply may be used to excite input and feedback transducers
- specifications for ±12.0 vdc regulated supplies are
  - voltage = 12.0 ± 0.5 vdc
  - load regulation ≤ 0.05 vdc for 10 to 150 madc load
  - line regulation ≤ 0.06 vdc for 105 to 125 vrms input line variation
  - ripple < 0.010 v p-p

Circuit Configuration

A power transformer having dual primary coils is used to accommodate either 115 vac or 230 vac, single phase power. A full wave diode rectifier circuit is used (D5-D8), together with substantial smoothing by C2 and C3.

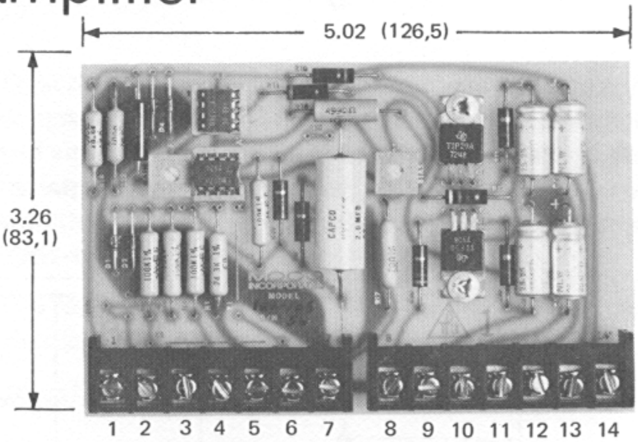
The regulated ±12.0 vdc ($\pm E_2$) is obtained by two integrated circuit voltage regulators, VR1 and VR2. Each regulator contains thermal overload shut-off protection.



Model 122-105 Basic Servoamplifier

This Snap Trac circuit card contains a complete dc servoamplifier. It is recommended for closed loop applications having single or multiple inputs and feedbacks. The output is an excellent current driver for almost any Moog servovalve.

The Model 122-105 requires a ± regulated dc power supply. This supply is provided by the Model 121-103 Servocontroller, so the Model 122-105 is usually used as an add-on where more than one servoamplifier is required. The servoamplifier portion of the Model 121-103 is identical to the circuitry in the Model 122-105.



MAXIMUM COMPONENT HEIGHT 0.70 (17,8)

Electrical Specifications

Type Servocontrol

- proportional or integral
  - ○ remove capacitor C1 for proportional control
  - ○ remove resistor R7 for integral control
- lag-lead control
  - ○ remove jumper and insert resistor R20 for lead corners
  - ○ substitute desired resistor R7 for lag corner

Inputs

- three standard inputs at terminals 2, 3, and 4
  - ○ 100KΩ input impedance (R2, 3, 4)
  - ○ other resistors from 10KΩ to 1 MΩ may be used
  - ○ signal levels from ±5 mvdc to ±200 vdc
- special input at terminal 6
  - ○ insert resistor at Ƶ1 for proportional input
    - ○ jumper to pin 2 of A1 for normal input
    - ○ jumper to pin 3 of A1 for differential input (i.e., summing two input signals of like polarities)
  - ○ insert capacitor at Ƶ2 for differentiating input
- one inner loop input at terminal 1

Output

- saturation current output is
  - ○ $i_o \max \geq \dfrac{9.0 \text{ vdc}}{R_{14} + R_{17} + \text{load R}}$ amps

    (R's in ohms)
  - ○ minimum load resistance 50 ohms
- consult the factory for higher output current capability

Drift

- with 100 KΩ inputs and with servoamplifier gain greater than 50 madc/volt, the maximum drift (referred to the input) is 0.15 mv/°C over the temperature range 0°C to 50°C

Frequency Response

- using proportional control to drive the torque motor coils of a servovalve, and within voltage saturation limits, the frequency response is less than 3 db down at 400 Hz

Gain

- potentiometer R8 provides about 20:1 range of gain control
  - ○ approximately 5 to 100 madc/volt for standard proportional control
  - ○ approximately 25 to 500 madc/volt sec for standard integral control
  - ○ other 20:1 ranges may be achieved by appropriate change of feedback components R7 or C1, or input resistors (R2, R3, R4)
    - ○ maximum gain 10,000 madc/volts
    - ○ general expression for approximate proportional gain (R8 fully CW)

$$i_o \simeq \frac{R_{16} \cdot R_7}{R_9 \cdot R_{17}} \left(\frac{e_2}{R_3} + \frac{e_3}{R_2} + \frac{e_4}{R_4}\right) \text{ ma}$$

(R's in KΩ)

    - ○ general expression for approximate integral gain

$$i_o \simeq \frac{R_{16}}{R_9 \cdot R_{17} \cdot C_1} \left(\frac{e_2}{R_3} + \frac{e_3}{R_2} + \frac{e_4}{R_4}\right) \frac{\text{ma}}{\text{sec.}}$$

(R's in KΩ; C in farads)

- 0 to 100% potentiometer control for e_2 available on special order
- inner loop gain at terminal 1 fixed
  - ○ gain with standard amplifier 5.0 madc/volt
  - ○ general expression for approximate gain

$$i_o \simeq \frac{R_{16}}{R_{17}} \left(\frac{e_1}{R_{18}}\right) \text{ ma}$$

(R's in KΩ)

Electrical Power Required

- ±12.0 vdc, regulated, 3-wire ($\pm E_2$) at ±8 madc, and ±14 to 20 vdc, unregulated, 2-wire ($\pm E_1$) at ±60 madc
  - ○ these voltages are available from the Model 121-103 Snap Trac Servocontroller
- alternate power supply ±14 to ±16 vdc, regulated, 3-wire at ±68 madc
  - ○ connect + to terminals 12 and 13 ($+E_2$ and $+E_1$)
  - ○ connect – to terminals 9 and 10 ($-E_1$ and $-E_2$)
  - ○ connect common to terminal 11

Circuit Configuration

The Model 122-105 contains an operational amplifier input stage (A1), an operational amplifier current drive stage (A2), and a complimentary pair of transistors (Q1, Q2) for current boost. The input stage will accept multiple signals (terminals 2, 3, 4). An additional input can be obtained at terminal 6 by mounting a suitable component at Z1 and connecting to A1. If this connection is to pin 3 (+ A1) the signal at terminal 6 will be differentially summed. A capacitor may be used at Z2 to provide a derivative input at terminal 6.

Input stage A1 may be used to provide either proportional or integral control. Every servoamplifier card contains components for both proportional and integral control, so it is necessary to remove the undesired component by clipping its leads. Capacitor C1 is removed to provide proportional control. Resistor R7 is removed for integral control. An additional resistor may be soldered in at R20 to give lag-lead control.

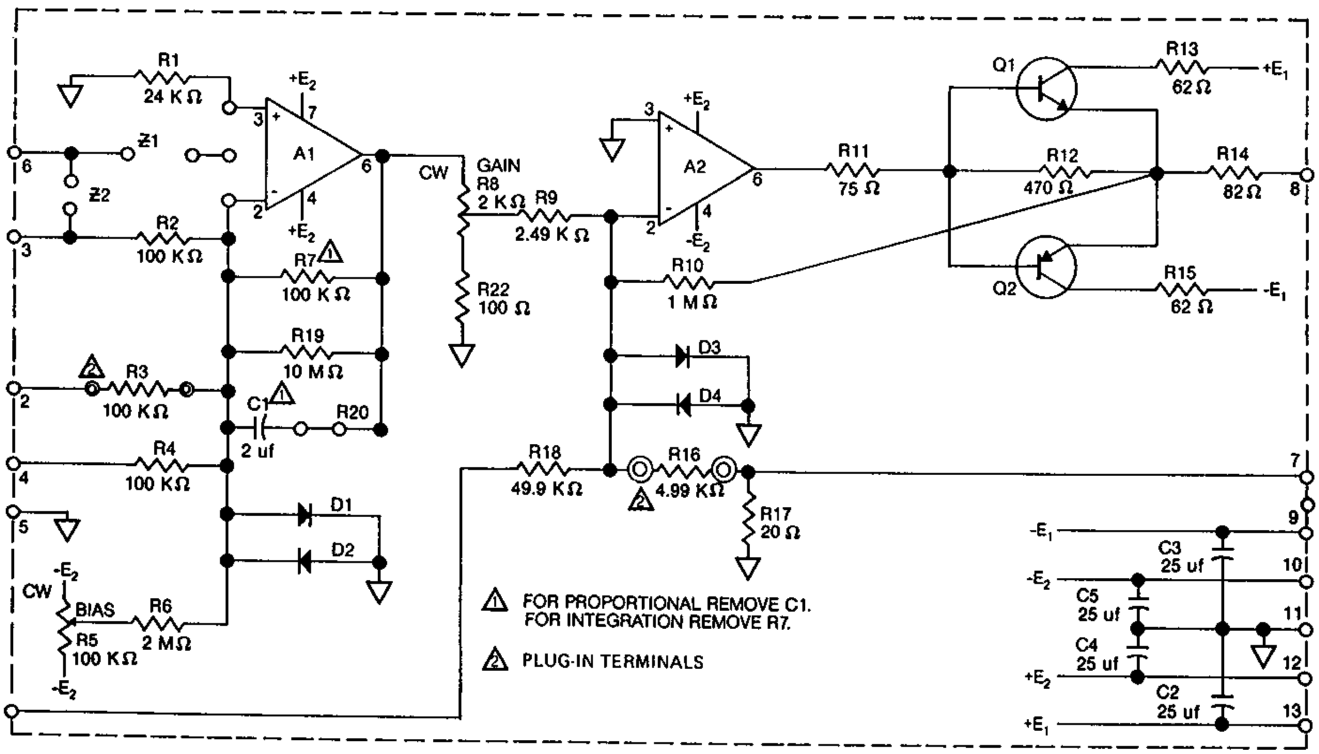
A null bias control is provided by potentiometer R5. Diodes D1 and D2 protect amplifier A1 from inadvertent oversignal conditions.

Servoloop gain is set by potentiometer R8. Location of this gain adjustment after the input stage provides full range gain control for either proportional or integral operation. Likewise, if lag-lead compensation is used, the gain change will not affect the compensation corner frequencies.

The output of stage A1 is summed with an additional input (terminal 1) at the current drive stage (A2). This additional input allows an inner loop feedback independent of outer loop gain and signal shaping. This inner loop is convenient when using three-stage servovalves. It also permits use of an electrical feedback pump stroker (Model 62-600) in a hydrostatic velocity servo having outer loop tachometer feedback.

Terminal 1 is also convenient for injecting a dither signal independent of the gain or dynamic characteristics of stage A1. Diodes D3 and D4 provide oversignal protection for the input of amplifier A2.

Servovalve coils are connected between terminals 7 and 8. Coils of Moog 62 Series Servovalves and pump strokers should be connected in series (27 ohms/coil). A parallel coil connection is recommended whenever the resulting amplifier load resistance will not be less than 50 ohms. Resistor R17 provides current feedback.



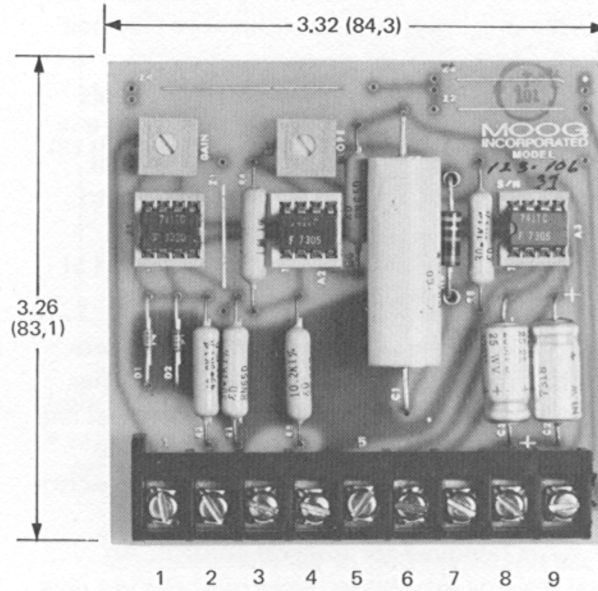
Model 123-106A Auxiliary Function Module

This Snap Trac circuit board contains two general purpose auxiliary functions:

(a) an uncommitted operational amplifier, and

(b) an up/down integrator.

The operational amplifier can be used for additional signal summation, signal shaping, and gain control. The up/down integrator can be used for acceleration/deceleration control of a velocity servo, or velocity ramp control of a position servo, or jerk control in a force loop.



MAXIMUM COMPONENT HEIGHT 0.65 (16,5)

Electrical Specifications

OPERATIONAL AMPLIFIER

Input

- one standard input at terminal 2
  - input impedance (R2) 49.9KΩ
  - other resistors from 10KΩ to 1 MΩ may be used
  - input signal levels from ±5 mvdc to ±200 vdc
- one special input at terminal 8
  - add input impedance as desired
  - jumper impedance to amplifier input pin 2 or 3

Gain

- potentiometer R3 provides gain change from 0 to 2
- other input or feedback resistors can be substituted for other gains

$$e_1 = -\left(\frac{R_3}{R_2}\right) e_2$$

Output

- output signal voltage may drive several other amplifiers
  - minimum load impedance 2,000Ω

Drift

- <0.15 mv/°C (referred to the input) over temperature range 0° to 50°C

UP/DOWN INTEGRATOR

Input

- 0 to ± E_2 at terminal 3

Output

- maximum rate of change adjustable from approximately 0.02 to 0.2 volts/sec by potentiometer R7
  - faster rate of change may be obtained by reducing the value of plug-in resistor R9 (minimum resistance 50KΩ)
- output final value is 75% of input
- if input signal is <±9 vdc, then R10 can be removed to have ± output final value = ± input
- output signal voltage may drive several other amplifiers
  - minimum load impedance 2,000Ω

ELECTRICAL POWER REQUIRED

- approximately ±8 madc of regulated, 3-wire, ±12 vdc to ±15 vdc

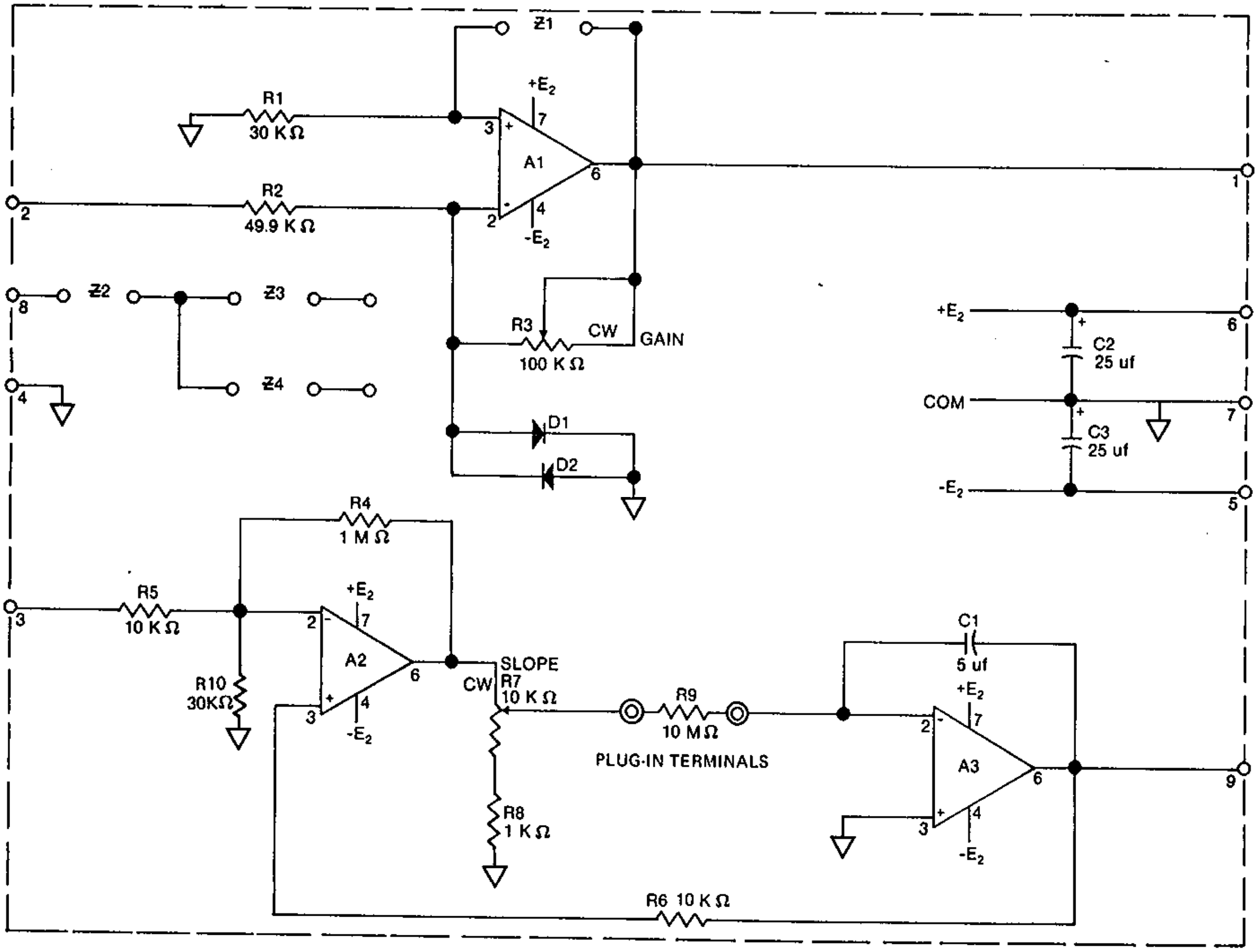
Circuit Configuration

The uncommitted operational amplifier, A1, has a single input (terminal 2) and output (terminal 1) wired in. Amplifier feedback is settable by potentiometer R3 for gain control. An additional input can be added (Z2) and additional feedback components can be used (Z1). Diodes D1 and D2 protect the amplifier from inadvertent oversignals at the amplifier input.

The up/down integrator consists of a comparator amplifier (A2), and an integrating operational amplifier (A3). Input signals are applied to terminal 3, and output is at terminal 9.

When an input signal is applied, integrating amplifier A3 ramps up (or down, as the case may be) at a rate established by R7. The output voltage is fed back by resistor R6. This feedback shuts-off amplifier A2 when the voltage output essentially equals the voltage input. When the input signal changes rapidly, the output signal will change at the controlled rate until the output signal amplitude and polarity equal the input signal.

The Model 123-106A can be powered by the Model 121-103 Snap Trac Servocontroller.



Applications of Snap Trac Electronics

The following examples show the application of Snap Trac Electronics with Moog's electric controller for hydrostatic drives. These examples illustrate the simple connections needed to create various servoloops. Snap Trac Electronics are just as easily used with other Moog servovalves to create position, velocity, and force servoloops.

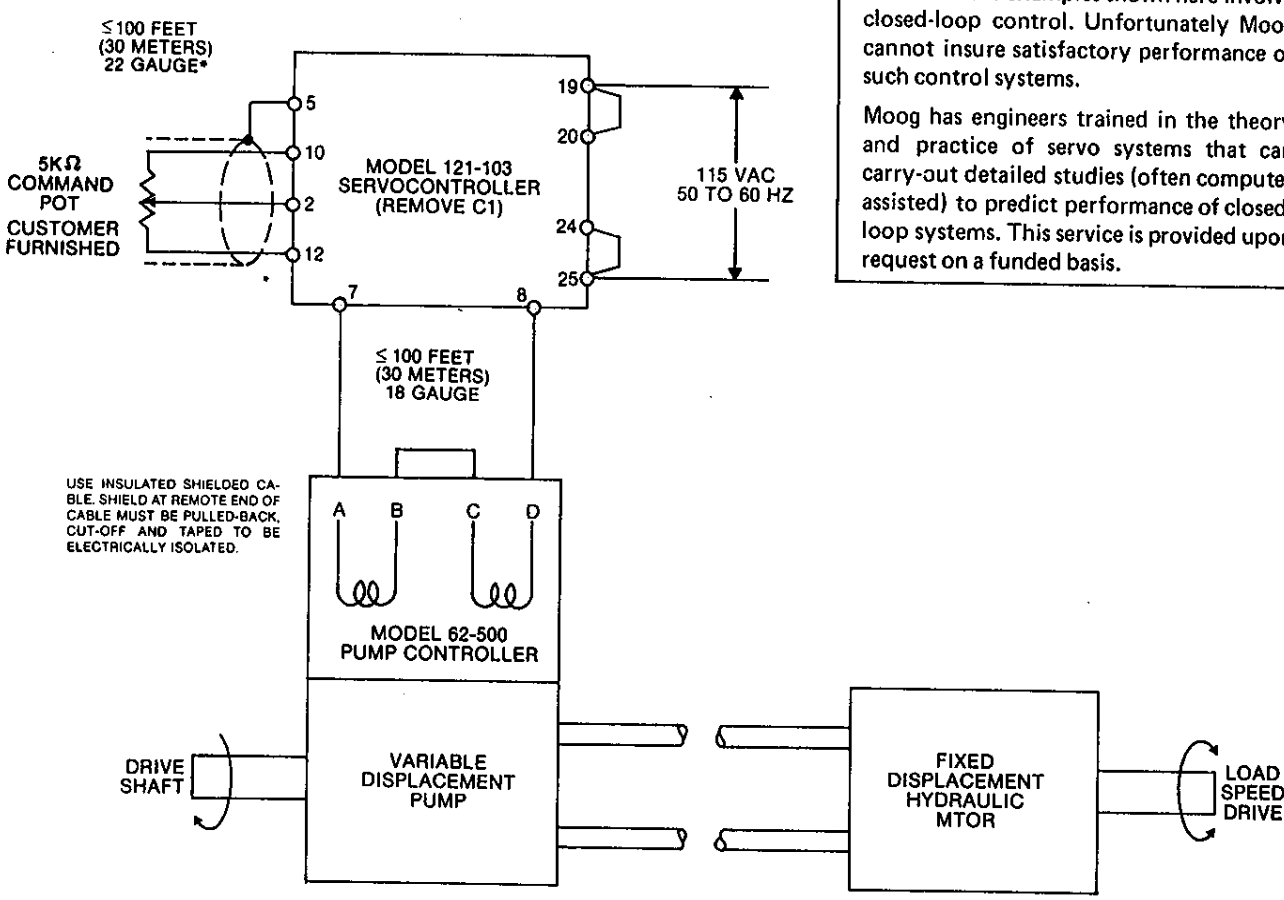
A Word of Caution

Stability of a closed-loop control system, together with adequate performance, is often difficult to achieve. Each individual component may perform perfectly, yet connection of the components into a closed-loop may result in hunting, oscillation, wild overshoot, chatter, sluggishness, poor resolution, hardover, drift, or what-have-you. The type of load, length of hydraulic lines, sizing of valve and actuator, loop gains, presence of backlash, friction, load limiters, compliance, location of feedback transducers, or other individual system idiosyncrasies can contribute to unacceptable closed-loop behavior.

Several of the examples shown here involve closed-loop control. Unfortunately Moog cannot insure satisfactory performance of such control systems.

Moog has engineers trained in the theory and practice of servo systems that can carry-out detailed studies (often computer assisted) to predict performance of closed-loop systems. This service is provided upon request on a funded basis.

OPEN-LOOP CONTROL OF HYDROSTATIC DRIVE

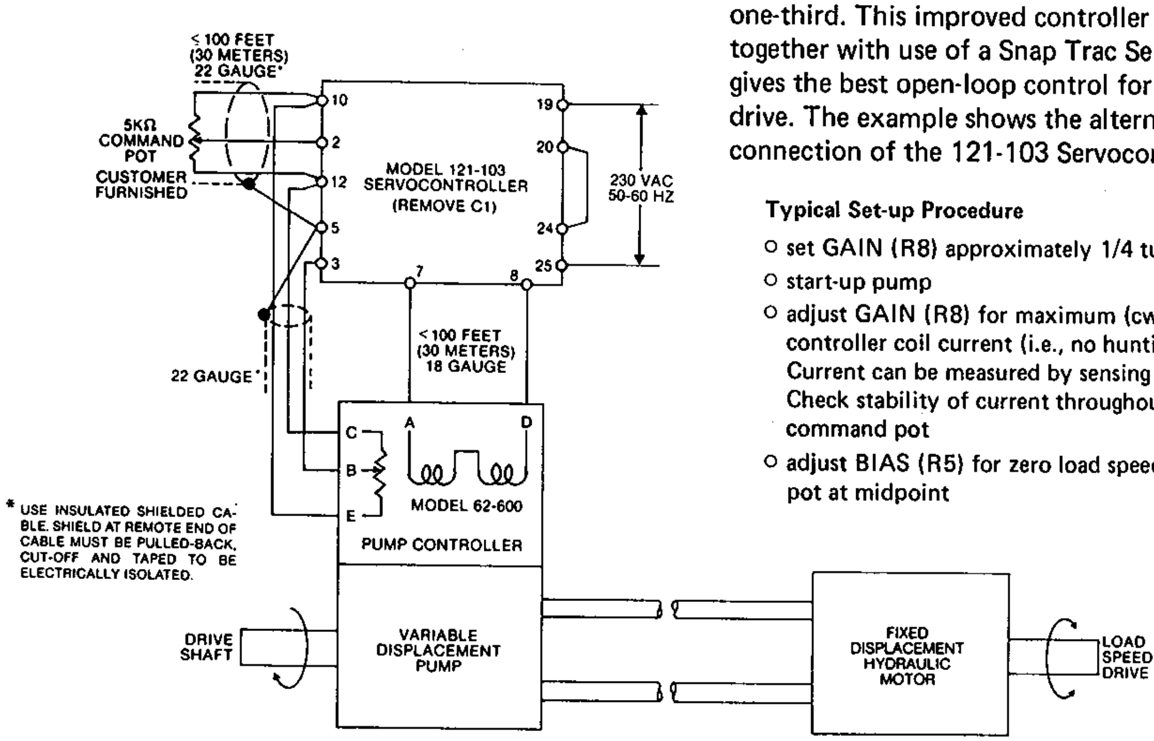


Moog's pump controller uses a dc control signal. When 115 vac is available, the Model 121-103 Snap Trac Servocontroller provides a convenient drive circuit for the pump controller. The stabilized power supplies and current feedback of the 121-103 eliminate unwanted control signal variations. The external velocity command pot can be located in an operator's control console.

Typical Set-up Procedure

- set GAIN at minimum (turn R8 fully ccw)
- adjust BIAS (R5) for zero controller coil current at mid-stroke of command pot. Coil current can be measured by measuring voltage at (7) and dividing by 20Ω (R17)
- start-up pump
- set GAIN (R8) for convenient sensitivity of command pot

IMPROVED INDUSTRIAL OPEN-LOOP CONTROL

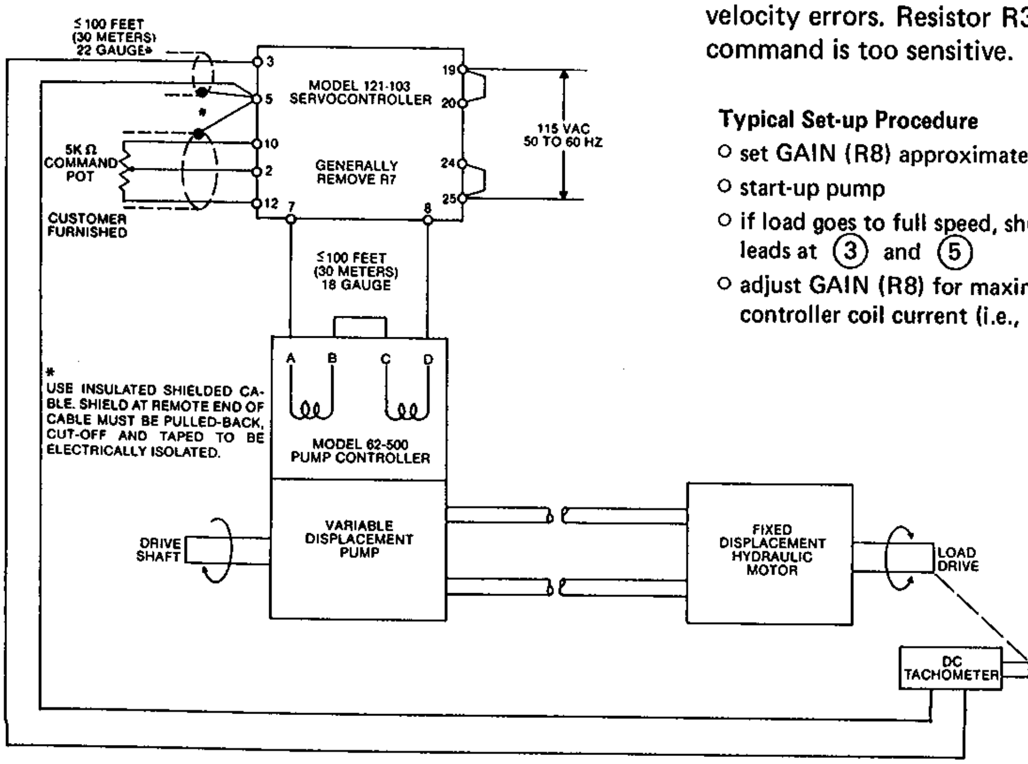


The electrical feedback pump controller reduces inaccuracies of swashplate positioning by about one-third. This improved controller performance, together with use of a Snap Trac Servocontroller, gives the best open-loop control for a hydrostatic drive. The example shows the alternate 230 vac connection of the 121-103 Servocontroller.

Typical Set-up Procedure

- set GAIN (R8) approximately 1/4 turn from full ccw
- start-up pump
- adjust GAIN (R8) for maximum (cw) with stable controller coil current (i.e., no hunting nor oscillation). Current can be measured by sensing voltage at (7). Check stability of current throughout full range of command pot
- adjust BIAS (R5) for zero load speed with command pot at midpoint

CLOSED-LOOP CONTROL OF HYDROSTATIC DRIVE IN MOBILE VEHICLE



A dc tachometer can be connected to the load to give closed-loop speed control. Generally resistor R7 is removed (leaving C1) to provide integral control. This will result in negligible static load velocity errors. Resistor R3 can be increased if the command is too sensitive.

Typical Set-up Procedure

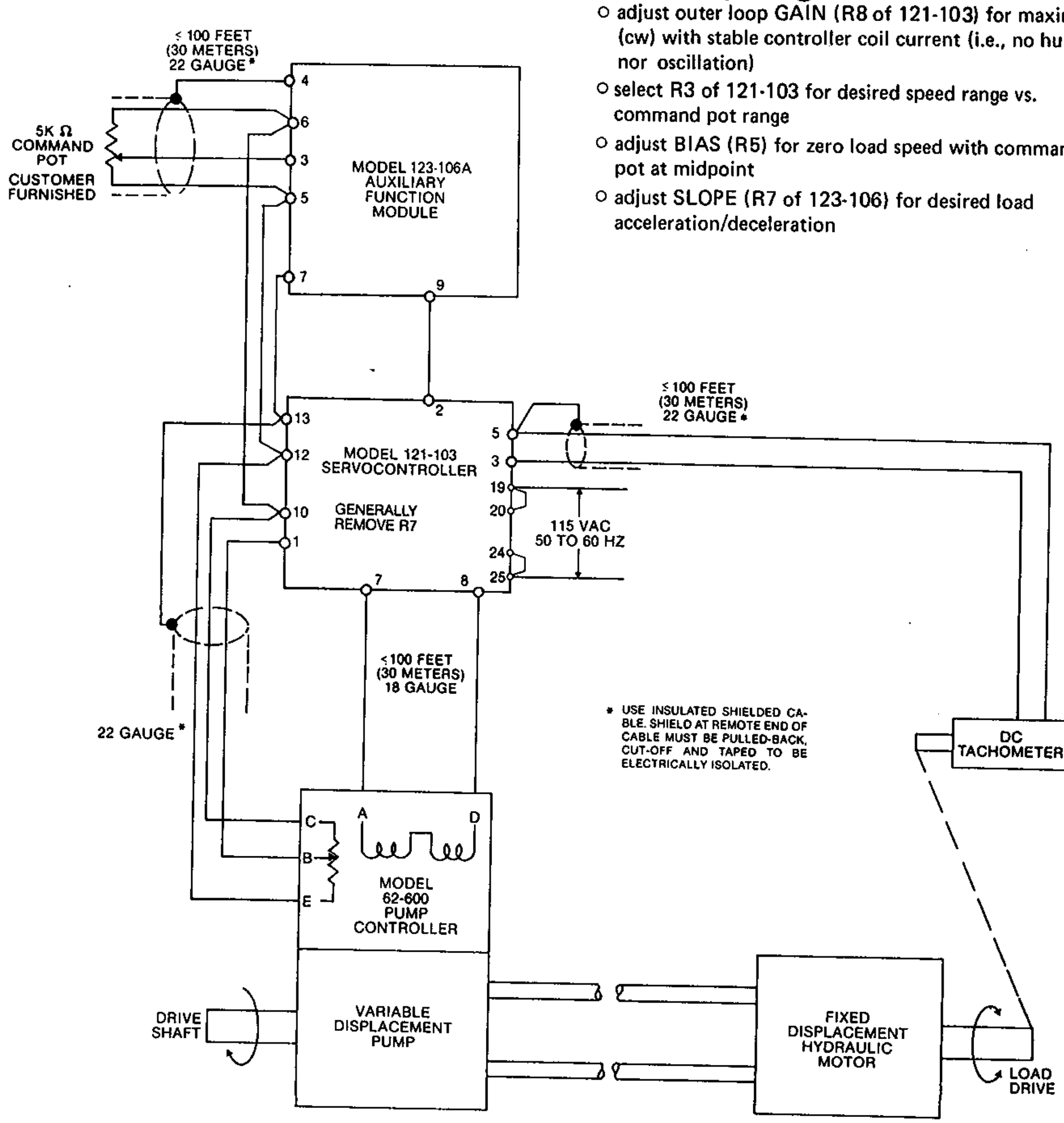
- set GAIN (R8) approximately 1/4 turn from full ccw
- start-up pump
- if load goes to full speed, shut off pump and reverse tach leads at (3) and (5)
- adjust GAIN (R8) for maximum (cw) with stable controller coil current (i.e., no hunting nor oscillation) Current can be measured by sensing voltage at (7)
- Select R3 for desired speed range vs. command pot range
- Check stability of current throughout full range of command pot
- adjust BIAS (R5) for zero load speed with command pot at midpoint

CLOSED-LOOP VELOCITY CONTROL WITH ACCELERATION/DECELERATION LIMIT

This example combines the Model 123-106A Auxiliary Function Module and the Model 121-103 Servocontroller in a closed-loop velocity servo. The electrical feedback pump controller is used to give better dynamic accuracy. R16 of Model 121-103 should be changed to a higher value (or removed entirely) to increase inner loop gain. Also, R7 is generally removed to give integral control for improved static accuracy.

Typical Set-up Procedure

- disconnect tach lead (3)
- set GAIN (R8 of 121-103) approximately 1/4 turn from full ccw
- start-up pump
- set inner loop gain (by appropriate selection of resistor R16) for maximum with stable controller coil current (i.e., no hunting nor oscillation). Current can be measured by sensing voltage at (7). Check stability of current throughout full range of command pot.
- connect tach lead (3)
- if load goes to full speed, shut off pump and reverse tach leads (3) and (5)
- adjust outer loop GAIN (R8 of 121-103) for maximum (cw) with stable controller coil current (i.e., no hunting nor oscillation)
- select R3 of 121-103 for desired speed range vs. command pot range
- adjust BIAS (R5) for zero load speed with command pot at midpoint
- adjust SLOPE (R7 of 123-106) for desired load acceleration/deceleration

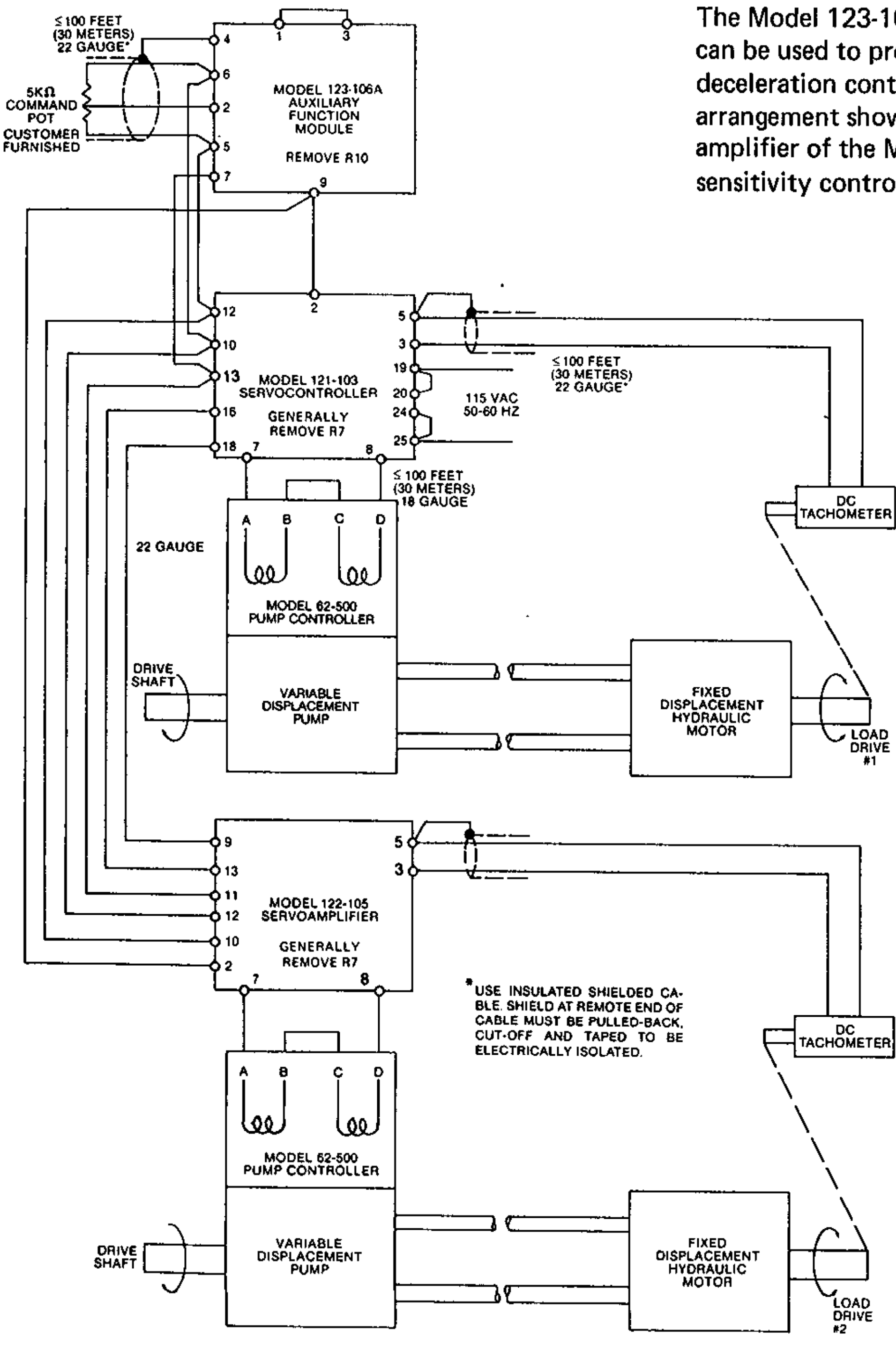


DUAL CHANNEL CONTROL USING ADD-ON SERVOAMPLIFIER

Systems that require two or more axes of control can make use of the 122-105 Servoamplifier. This snap trac card is powered from the Servocontroller for an economical add-on combination.

The example shows a common velocity command pot for two, independent load drives. Velocity feedback is used with each drive for better velocity tracking than would be achieved with open-loop control.

The Model 123-106A auxiliary function module can be used to provide a common acceleration/ deceleration control for both load drives. In the arrangement shown the variable gain operational amplifier of the Model 123-106A provides a velocity sensitivity control.



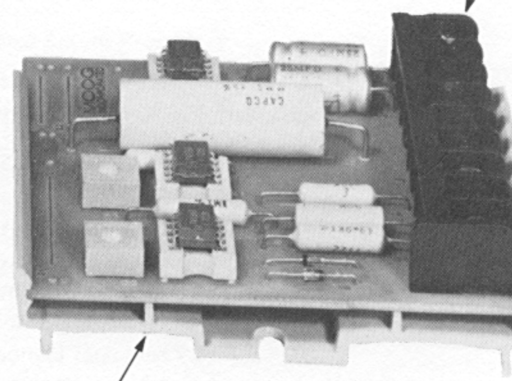
Typical Set-up Procedure

- set GAINS (R3 of 123-106A; R8 of 121-103; and R8 of 122-105) approximately 1/4 turn from full ccw
- start-up pumps
- if either load goes to full speed, shut off pumps and reverse corresponding tachometer leads at (3) and (5)
- adjust each GAIN R8 for maximum (cw) with stable controller coil current (i.e., no hunting nor oscillation). Current can be measured by sensing voltage at (7)
- adjust each BIAS (R5) to give zero load speed with command pot at midpoint
- adjust sensitivity GAIN (R3 of 123-106A) for desired sensitivity of command pot
- if different speed ranges of the two load drives are desired, select R3 of 121-103 and R3 of 122-105 accordingly
- recheck stability of controller coil current throughout full range of command pot
- adjust SLOPE (R7 of 123-106A) for desired load acceleration/deceleration

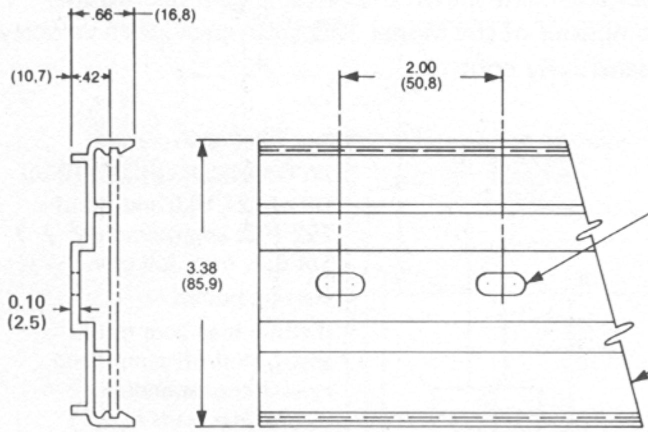
Physical Arrangement

Moog Snap Trac Electonics fit the Curtiss Type TR-3 plastic (PVC) tracks (available from Moog as P/N 146-65419-1). These tracks are supplied in 4-ft. lengths, then cut to suit. The tracks are usually screwed or riveted inside the electrical equipment panel.

Each circuit card, or other electrical component packaged for the Snap Trac, snaps into position anywhere along the track length. Necessary interconnections are made without the need for expensive cables and connectors.



(DIMENSIONS IN PARENTHESIS ARE MILLIMETERS)



*Curtis Development & Mfg. Co.
3266 N. 33rd St.
Milwaukee, Wis. 53216

Circuit Cards

All Moog Snap Trac cards have printed circuits on epoxy glass boards. The electronics are completely solid-state. All electrical components are mounted on one side of the board which is clearly marked for quick identification of components.

Single turn, screwdriver operated trim pots are used for various circuit adjustments.

Moog Snap Trac circuit cards use screw terminals for external connections. These provide rugged and reliable electrical connections where initial installation or replacement can be accomplished quickly without soldering. Each screw has a wire grip washer that eliminates the need for lugs on the connecting wires. Each screw will accept at least one #14, or two #18, or four #20 connecting wires. The terminal strips have side and back barriers about each screw to prevent over-insertion of wires, or terminal-to-terminal wire shorts.

Environmental Protection

Snap Trac circuit cards are intended to be mounted within an electrical equipment cabinet that will provide adequate environmental protection. Outdoor installations should have a NEMA 4 or equivalent cabinet, and all cabinet penetrations should be sealed.

Location of a servoamplifier within an equipment cabinet is generally not critical; however, it should not be located alongside electrical motor controllers or other components that have high electromagnetic radiation, without suitable shielding.

Moog Snap Trac circuit cards can be supplied (on special order) with a surface coating that will reduce susceptibility to moisture and high humidity.

Industrial quality solid-state components are used in standard Snap Trac circuit cards. Recommended temperature range is –20° to +60°C (–4° to +140°F).