Application

The PID Controller provides a means of controlling the output shaft speed of a hydrostatic transmission. By comparing actual motor speed against a setpoint command and using proportional, integral and derivative stages that operate on the error, accurate and responsive control is achieved.

In a typical application, the PID Controller maintains an accurate output shaft speed on a hydrostatic transmission coupled to the vibratory drive of a roller compactor. Other applications include motor generator frequency control, motor speed control for resonant beam systems, crawler forward speed control or torque control for pressure-control pumps. A series of parameters is varied for each individual application.

The MCE100A senses output speed with either a pulse pickup or a dc tachometer feedback. For those cases in which maximum response to pump RPM changes is necessary, a feedforward MC Controller is also available.

Features

- Withstands mobile equipment vibration and shock conditions
- Electronic components selected and tested for mobile environmental conditions
- Printed circuit boards coated with electronic-grade conformal coating for moisture protection
- Reverse polarity protection
- Short circuit protection
- Shorted valve + lead will not damage unit
- Loss-of-feedback protection for open or shorted wires
- Maintains setpoint upon loss of feedforward sensor
- Ramp startup

Specifications

Electrical

INPUT VOLTAGE RANGE
11 to 16 Vdc (12 volt models)
20 to 28 Vdc (24 volt models)

SUPPLY CURRENT (EXCLUDING LOAD CURRENT)
100 ma, maximum

OUTPUT VOLTAGE AT 4 VOLT TERMINAL (V_R)
4 ± .4 Vdc

FEEDBACK INPUT VOLTAGE
.5 - 20 volts, peak to peak (pulse pickup)
0 - 4 volts dc (protected to 16 Vdc) (dc tachometer)

FEEDBACK INPUT IMPEDENCE
.01 µf paralleled with 50 k Ω (pulse pickup)
40 k Ω (dc tachometer)

FEEDBACK DUTY CYCLE (PULSE PICKUP)
30 - 70%

FEEDFORWARD INPUT VOLTAGE
.5 to 20 Vdc, peak to peak (pulse pickup)

FEEDFORWARD CORRECTION RANGE
425 Hz, maximum (pulse pickup)
100 Hz, minimum (pulse pickup)
For non-standard frequencies, see Ordering Information

FEEDFORWARD INPUT IMPEDANCE
.01 microfarads paralleled with 50 kilohms (pulse pickup)

EXTERNAL COMMAND INPUT VOLTAGE RANGE
0 TO 4 Vdc

EXTERNAL COMMAND INPUT IMPEDANCE
200 kilohm, minimum

OUTPUT CURRENT RANGE (Current Source)
300 ma, maximum (V7058)
150 ma, maximum (MCV101A)

OUTPUT LOAD RESISTANCE
10 ohms, minimum

OUTPUT LOAD INDUCTANCE
.4 henries, maximum

METER CURRENT ADJUST
450 to 800 microamps at maximum setpoint

REVERSE POLARITY
The power and ground inputs may be reversed without incurring damage to the device.

SHORT CIRCUIT PROTECTION
The valve output will sustain indefinite short circuits to ground.

TRANSIENT PROTECTION
The valve output will sustain inductive switch transients of less than 15 millijoules.

OPEN FEEDBACK PROTECTION
150 msec, maximum
Defined as the time from loss of feedback to zero output current when operating at 50% of full scale command. For non-standard values, see Ordering Information.

Environmental

OPERATING TEMPERATURE
-29° to +66° C (-20° to +150° F)

STORAGE TEMPERATURE
-34° to +66° C (-30° to +150° F)

VIBRATION
Withstands a vibration test designed for mobile equipment controls consisting of two parts:

1. Cycling from 5 to 2000 Hz in each of the three axes.
2. Resonance dwell for one million cycles in each of the three axes.

Run from 1 g to 8 g's. Acceleration level varies with frequency.

SHOCK
50 g for 11 milliseconds. Three shocks in both directions of the three mutually perpendicular axes for a total of 18 shocks.

HUMIDITY
After being placed in a controlled atmosphere of 95% humidity at 38° C (100° F) for 10 days, the controller will perform within specification limits.

RAIN
After being showered from all directions by a high pressure hose down, the controller will perform within specification limits.

Performance

SETPOINT STABILITY
Less than .5% of setting over supply range
Less than 2% of setting over temperature range
Defined as the percent of variation from setting in plant output in stable closed loop control.

COMMAND THRESHOLD
30 ± 2%, 18 ± 2%, 10 ± 2%, 2.5%
Defined as a percentage of full scale for lowest closed loop control.

COMMAND RAMP UP RATE
4.4 ± .8 seconds, 0.4 ± .2, 2.5 ± .8, 2.0 ± .8
Defined as the time for command input signal to reach 90% of full scale with internal or external command set to full scale.

DUAL RAMP UP RATE
.45 ± .07 seconds to reach 40%
6.3 ± .6 seconds to reach 90%
Defined as the time for command input signal to reach 90% of full scale with internal or external command set to full scale.

FEEDBACK FREQUENCY
500 Hz, 1 khz ± 1%, 1.1 khz ± 1%, 5 khz ± 1%, 3 khz ± 1%, 1.65 khz ± 1%
Defined with command set to maximum (+4 Vdc) and with stable, closed loop control. For non-standard feedback frequencies, see Ordering Information.

FEEDBACK PHASE ANGLE
41° ± 5° phase lead at 2 Hz modulation
0° ± 5°
Defined as the phase lead from the feedback input's sinusoidally varying frequency to the input.

FEEDFORWARD LOAD CURRENT CHANGE

100 ± 5 ma

Defined as the open loop change in load current output for an input frequency change of 1 khz to 5 khz. For non-standard changes, see Ordering Information.

PROPORTIONAL GAIN

.43 to 3.5 ma/%
.27 to 2.4 ma/%
.29 to 2.4 ma/%
.232 to 2.0 ma/%
.11 to .85 ma/%
.5 to 3.5 ma/%
.05 to .43 ma/%

Defined as the gain rates at the low and high ends of the proportional gain adjustment. For non-standard settings, see Ordering Information.

INTEGRATION TIME CONSTANT

100 to 300 msec, 100 to 1100 msec

For non-standard settings, see Ordering Information.

DERIVATIVE TIME CONSTANT

0 to 550 msec

For non-standard settings, see Ordering Information.

DIMENSIONS

See Figure 1.

Theory Of Operation

An internal or external command signal proportional to the desired hydrostatic transmission speed is input to the MCE100 PID Controller. See Figure 2. Command conditioning circuitry provides a slow ramp up to prevent excessive start up acceleration and a quick ramp down for safety in sudden stops. A low limit threshold must be crossed before any control action begins. This low speed limit is imposed by inherent constraints on the feedback pulse rate in a responsive closed loop control system and by loss of feedback considerations.

When the command exceeds the threshold point, it is compared to the feedback signal from the first pulse pickup. See Figure 3. The feedback has been converted from frequency to a dc voltage if the sensor is a pulse pickup. If a dc tachometer is substituted, this is unnecessary. After the feedback is subtracted from the command, a loss-of-feedback circuit monitors the output. If an excessive error signal exists for an extended duration of time (indicating a loss of feedback signal), the controller will latch off (on some units). A power down and back up cycle will effect a reset.

The error signal is then passed to the PID stages. The first correction mode, proportional (P), increases the corrective output in response to the magnitude of the error - the larger the error, the bigger the response. The proportional stage allows the system to respond almost immediately to changes. It acts in series with the paralleled I and D stages, as shown in Figure 2. The second correction mode, integral (I), increases the output with the integral of time - error is summed as time progresses, and by adding these signals over time even small errors can be recognized and corrected, giving zero-droop control. The third correction mode, derivative (D), increases the output with the derivative of time - fast changes produce a large corrective signal. The derivative stage adds stability to most systems.

The feedforward stage is an option for those applications needing further response in their systems. See Figure 4. A second pulse pickup on the pump input shaft senses prime mover speed input changes before they are reflected at the motor output shaft. Again, either a pulse pickup or dc tachometer may be used and a low-idle threshold must be crossed before corrective action begins. Because the feedforward signal is added algebraically to the output stage, a faulty sensor or broken wire will not stop the controlling action; two potentiometers set the zero and span of feedforward action.

The four signals are added in the summing stage, where they are converted to a current output to the pump stroker (V7058 or Electrical Displacement Control). The current level is varied by the controller to maintain the desired speed from the hydraulic motor's output shaft.

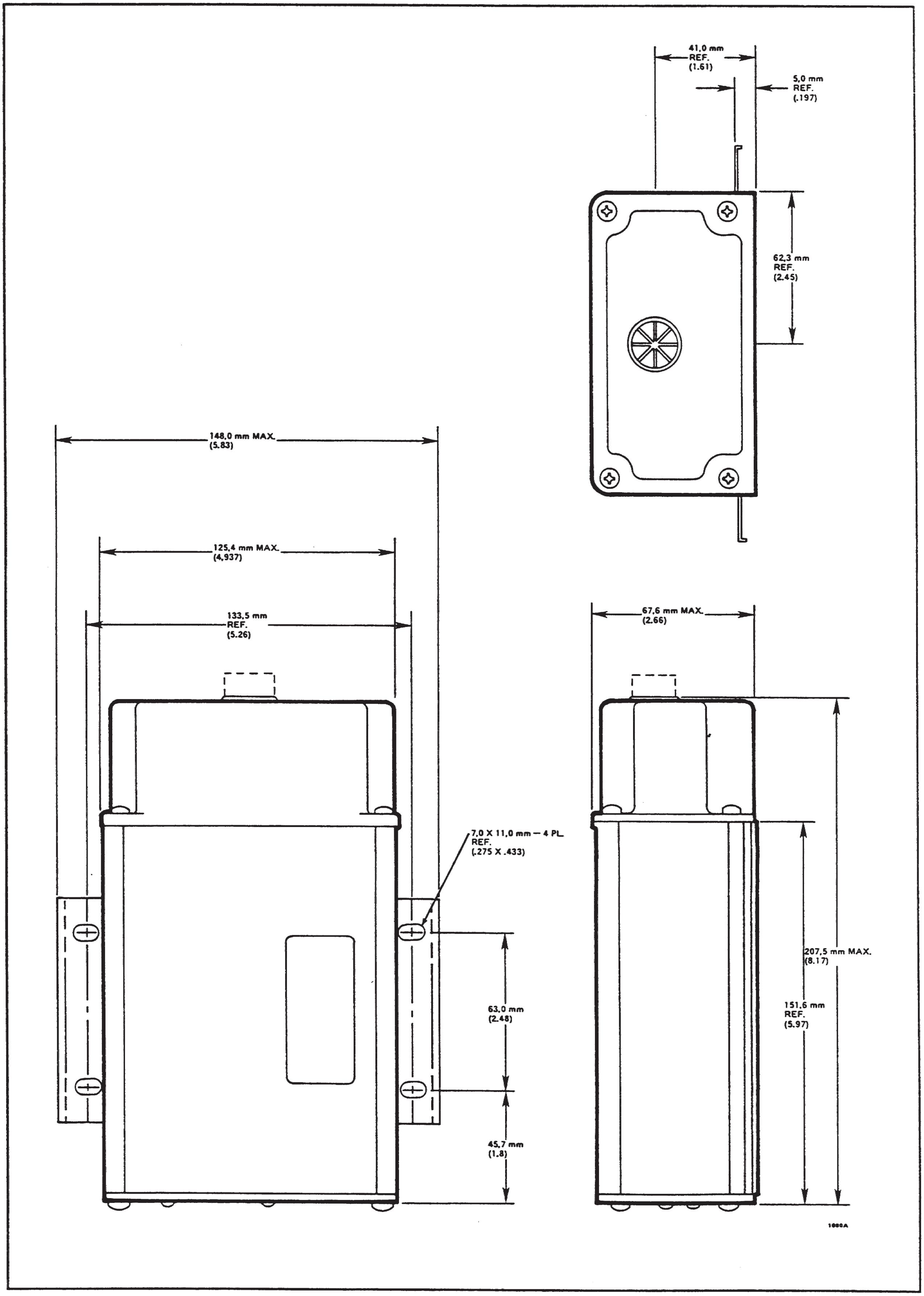

FIGURE 1. Dimensions of the MCE100A, B in millimeters (inches).

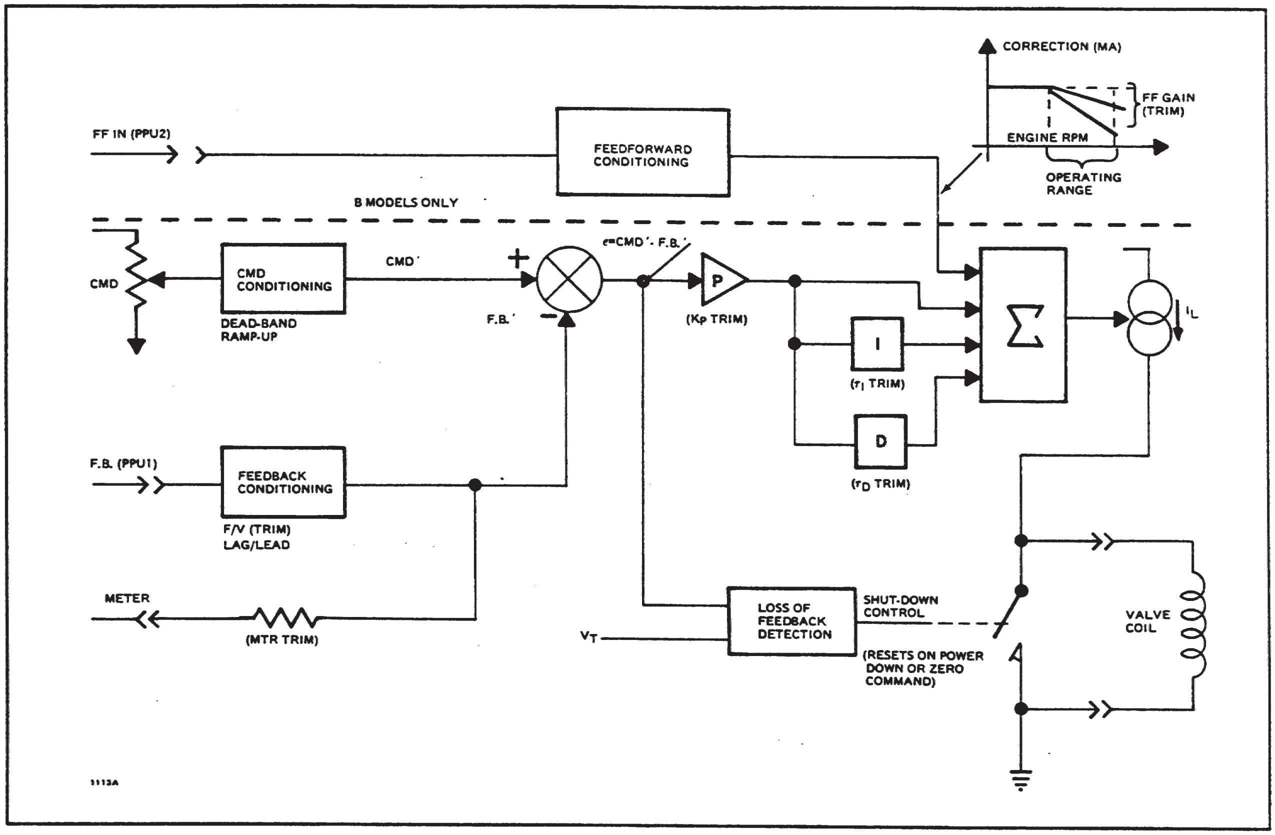

FIGURE 2. Three mode speed control functional diagram.

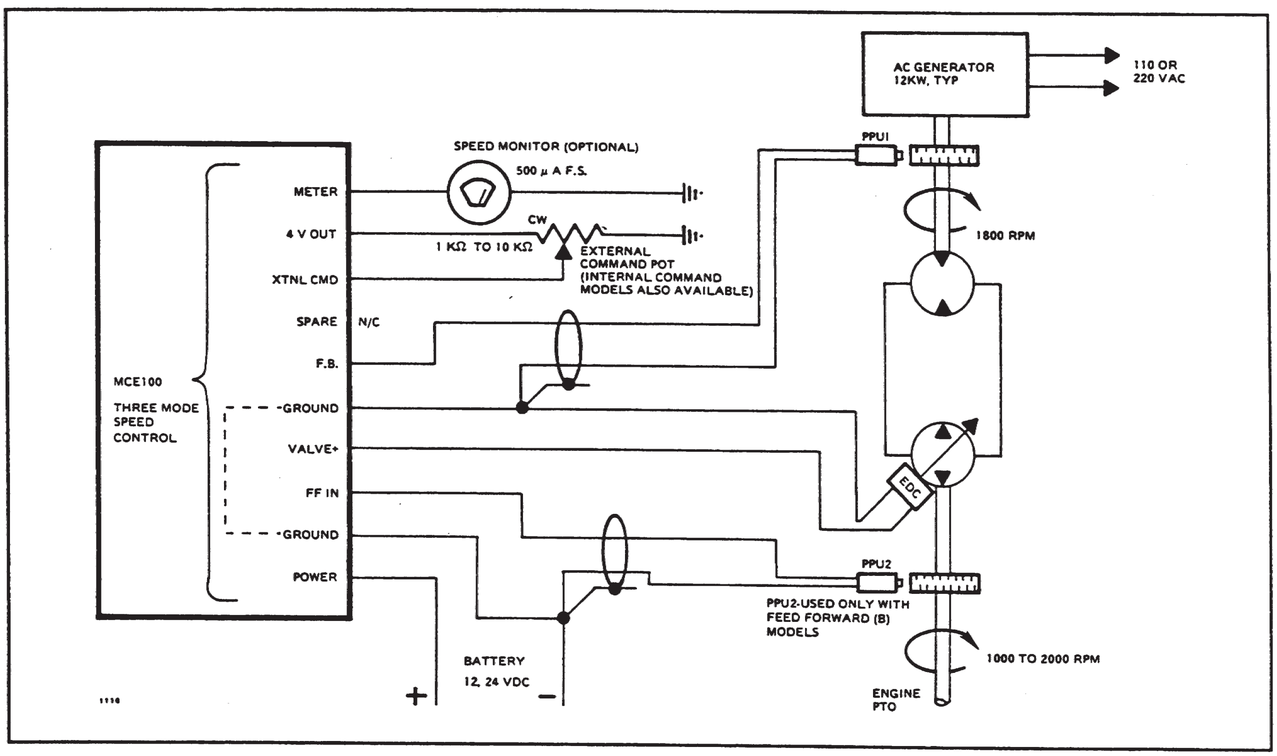

FIGURE 3. Typical generator control system.

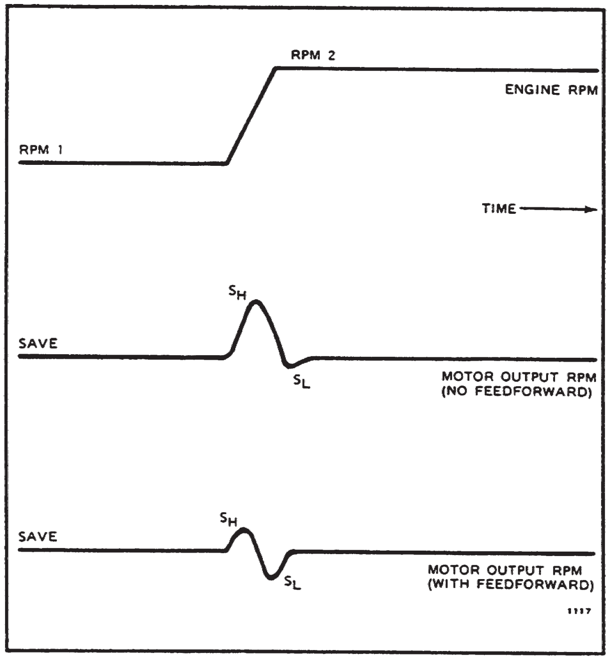

FIGURE 4. Effect of feedforward on control action. Peaks S_H and S_L have the same feedforward amplitude and are smaller than those of feedback only.

Wiring

Figure 5 shows a typical wiring connection for the PID control loop. The cable extending from the controller terminates in a connector that mates to a female MS connector, Bendix part number PT06-14-18S (left side of the connector, as diagramed). The MS connector attaches to a color-coded cable, which is fanned out into a customer-supplied terminal strip. If the customer chooses to connect directly to the terminal strip, the mate to the terminal is a number 4 spade lug.

The following cable/connector assemblies are available. See Figure 6.

1. One six-foot cable with the MS connector specified above.

2. One twenty-foot two wire valve cable with an amphenol 44-103-10002 connector and mate.

3. One twenty-foot two-wire Belden 9318 shielded feedforward or feedback cable with a pair of number 6 spade lugs on one end and a pair of 1/4 inch push-on terminals at the other.

Initial Installation

Overall System Considerations

For stable and responsive closed loop speed control, the open loop characteristics of the rest of the system should be optimized with the following criteria in mind.

- The system must be capable of delivering the selected RPM setpoint over the full range of engine input speeds and output loads. The smallest pump-to-motor size ratio should be chosen that meets this criterion.

- Pump/motor interconnect hoses are energy storage elements. Excessive length and/or diameter causes poor open loop transient response and loss of stability under closed loop control. Therefore, hose lengths should not exceed ten feet, and lines over three feet should not exceed three-quarter inch in diameter for high pressure hose. Longer lines may require hard piping.

- Load variation should not cause wide movements in engine RPM levels. A "soft" engine governor will result in a less responsive and less stable control loop.

- A standard feedforward frequency from the pump pulse pickup is 333 Hz at 2000 RPM (10 tooth gear), handled by the standard controller. Other frequency ranges may be accomodated, such as 500 Hz from an engine flywheel gear. Acceptable pulse pick-up voltages:
  500 MV peak to peak minimum,
  20 volts peak to peak maximum.

- The drive signal from the controller necessary for optimum performance depends on the type of pump stroker used.

- Controllers are available for either 12 or 24 Vdc systems.

- Because of their energy storage capabilities, pressure filters in the high side of the hydrostatic loop are detrimental to control performance.

- All pump and motor combinations may be equipped with speed control; however, optimal parameter settings will vary with each combination, as will control performance.

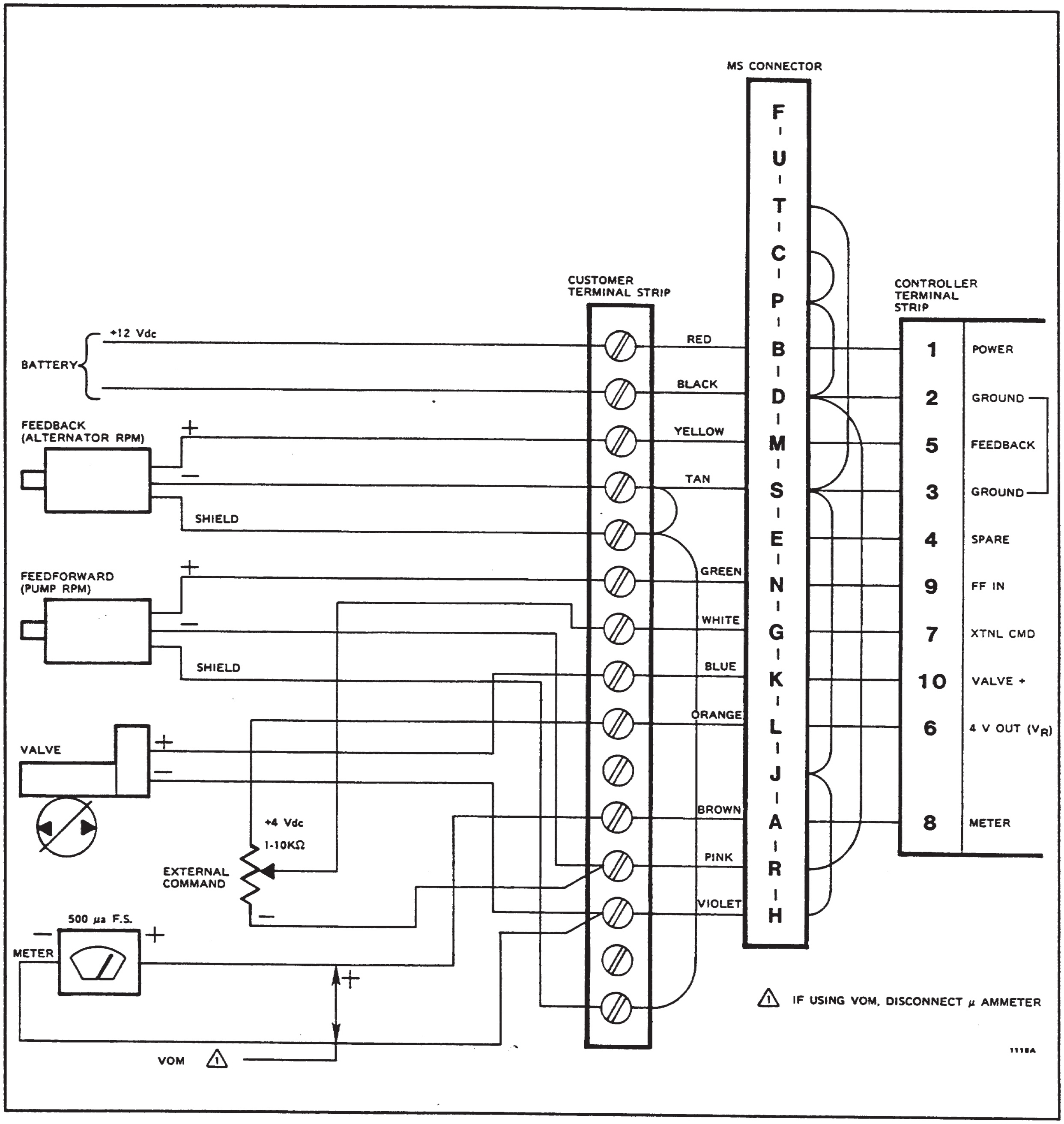

FIGURE 5. Wiring connection to the controller. All cables have one end with no termination; user cuts to length and terminates.

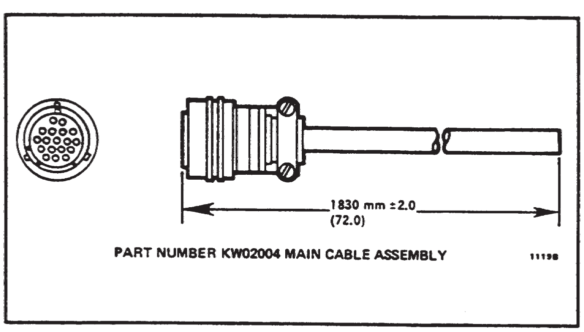

FIGURE 6. Main Cable Assembly.

Adjustment Procedure

Once familiar with the user's application, the PID Controller can be factory-shipped with standard potentiometer settings. If the application is new, or if the settings need re-adjustment due to wear in the hydrostatic transmission, hoses, control valves, etc., the procedure listed below should be followed to maximize the controller's efficiency. The procedure assumes that the user has either a voltmeter or oscilloscope attached to the controller to track system response.

Adjustment Procedure *(Continued)*

When making gain changes and testing for stability, it is recommended that small adjustments be made before upsetting the system and observing how it recovers. As the system approaches instability it will tend to "ring" somewhat before settling out. This helps identify when instability is being approached and minimizes the chance of a dangerous instability level, which could damage the equipment.

1. With the system fully connected, remove the controller's cover and locate the row of trim potentiometers on the main board and feedforward trim on the secondary board (if used). They are located near the plastic end cap. See Figure 7.

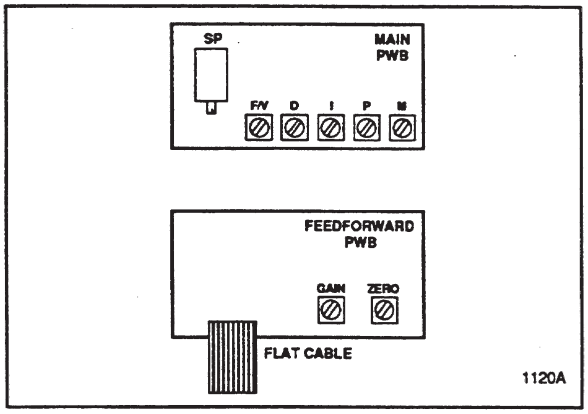

FIGURE 7. Location of setpoint trim potentiometers on the Controller's main printed circuit board.

2. Connect a voltmeter from terminal 8 to ground. A microammeter may be substituted for the VOM. Disconnect the microammeter if using a VOM.

3. Adjust the internal setpoint counterclockwise until a slight click is heard, indicating the minimum setpoint. Then adjust the setpoint clockwise (increasing speed) to bring the system to the desired speed. The potentiometer will require several turns to surpass the threshold and come up to the proper speed. External setpoint would be similarly operated.

4. Set the P potentiometer 90° clockwise from minimum; set I mid-position. Set D to its midpoint, as indicated in Figure 8. On the feedforward circuit board, set gain and zero potentiometers to their midpoint.

5. Set the engine at maximum RPM.

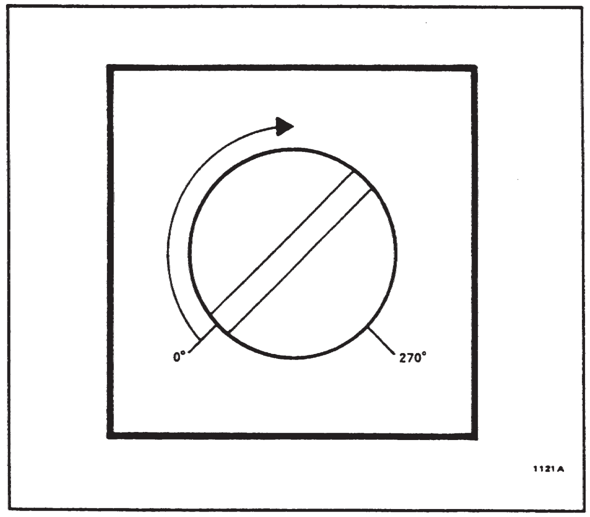

FIGURE 8. Adjustment range of the P, I, D and M setpoint potentiometers.

6. Apply power to the controller. If the system starts to oscillate, as indicated by severe vibration in the hydrostatic transmission, shut off power to the controller.

7. If the system oscillates and the driven load is massive and inertial, turn the D setting clockwise. If the system oscillates and the load is not massive turn it counterclockwise. Continue to adjust the D setting until the point that stability is achieved. If the system oscillates at all settings, consult Danfoss.

8. Increase the P gain until the system starts to go unstable or the maximum is reached. Then decrease the gain by 1/3 of distance from countercloskwise end.

9. Increase the I gain until the system starts to go unstable or the maximum is reached. Then decrease the gain by 1/3 of distance from counterclockwise end.

10. Re-adjust the D gain by varying to instability in either direction and then re-setting midway between these instability points.

11. Re-adjust the P gain by increasing it to instability and then backing away from this setting by 1/3 of the distance from the counterclockwise end.

12. Feedforward Adjustment:
    a) Set Feedforward gain to mid position.
    b) Set zero to mid position.
    c) Start and set engine to some mid RPM.
    d) Start full PID Control at about 25% of the rated speed at full engine.

e) Ground (or open) Feedforward pulse pickup.

f) As the Feedforward PPU ground is removed, the valve + (PID terminal 10) shall reduce momentarily (for less than 1 second). This can also be observed by a momentary drop in the set RPM. Adjust the Feedforward ZERO until the momentary voltage (speed) drop shows as the Feedforward PPU is re-enabled.

g) Make a step change (i.e., a sudden increase) to set engine to maximum throttle. Observe output speed deviations as the engine runs up. If the controlled hydrostatic output speed increases much as the engine runs up, increase Feedforward gain. Conversely, if output speed decreases momentarily, then reduce Feedforward gain.

h) There may be some over shooting during engine run up as shown in Figure 4. Adjust Feedforward gain for the least + or - speed changes. The adjustments of P, I, and D in the main PID board may also be varied to effect the least speed deviation as the engine runs up.

13. If a permanently-installed microammeter is to be used, the meter potentiometer (M) may be used for calibration. At a known output speed (verified by a stroboscope, oscilloscope, tachometer or other), adjust the meter potentiometer for the correct microammeter reading.

Troubleshooting

Should the speed control loop fail to maintain speed properly, any one of its components could be at fault. Table A provides a means of diagnosing these failures. Should the procedure fail to solve the problem, consult Danfoss. For PID Controllers that need repair, see Ordering Information.

TABLE A. Troubleshooting procedure for failures in the PID control loop. Symptoms are on the left and areas to check are on top. Areas should be checked in the numerical order shown (i.e., check "1"s first, "2"s second, etc.).

	FEEDBACK PPU FAULT		EXTERNAL CMD FAULT		POWER FAULT		VALVE FAULT		ENGINE RPM	FEEDFORWARD PPU	
	OPEN/ SHORT	INT △1	OPEN/ SHORT	INT	OPEN	LOW OR INT	OPEN/ SHORT	INT	LOW	OPEN/ SHORT	INT △1
1. WILL NOT TURN SYSTEM AT ALL			1		1		1				
2. MOTOR STARTS TO TURN, THEN SHUTS OFF	1	2		3	1	2	1	2	2		2
3. SYSTEM HUNTS EXCESSIVELY, NON-PERIODIC		1		1		1		1			1
4. SYSTEM RUNS OK, THEN SHUTS DOWN OR SPEEDS UP, THEN SHUTS DOWN		1		1				1			1
5. SYSTEM RUNS FULL SPEED	1		1/△2				1/△3				
6. CANNOT SET TO FULL SPEED		2		2		1			1		2
7. POOR RESPONSE TO RPM CHANGE										1	2
8. CANNOT MAKE SYSTEM STABLE (OSCILLATES CYCLICALLY)		3		5		4		4			3
9. ENGINE RPM AND SYSTEM BOTH OSCILLATE											
10. POOR RESPONSE TO LOAD CHANGE											
11. METER READ-OUT NOT WORKING (KNOW MICROAMMETER IS OK)											

△1 INT MAY BE INTERMITTENT CONNECTION ON EITHER WIRE OR MARGINAL VOLTAGE OFF SENSOR

△2 GROUND FAULT (OPEN)

△3 SHORT TO POWER SOURCE

△4 SYSTEM STABILITY IS ALSO AFFECTED BY THE ENGINE GOVERNOR

	METER OUT		INT OR EXT CMD		IM. PROPER P.I.D ADJ.	FEEDFORWARD GAIN		HOSE. LEN. DIA.
	OPEN/ SHORT	INT	TOO LOW	TOO HIGH		TOO LOW	TOO HIGH	TOO LAR.
1. WILL NOT TURN SYSTEM AT ALL			1					
2. MOTOR STARTS TO TURN, THEN SHUTS OFF								
3. SYSTEM HUNTS EXCESSIVELY, NON-PERIODIC								
4. SYSTEM RUNS OK, THEN SHUTS DOWN OR SPEEDS UP, THEN SHUTS DOWN								
5. SYSTEM RUNS FULL SPEED				1				
6. CANNOT SET TO FULL SPEED								
7. POOR RESPONSE TO RPM CHANGE						2		
8. CANNOT MAKE SYSTEM STABLE (OSCILLATES CYCLICALLY)					1		2	1
9. ENGINE RPM AND SYSTEM BOTH OSCILLATE					2/△4		1/△4	
10. POOR RESPONSE TO LOAD CHANGE					1			1
11. METER READ-OUT NOT WORKING (KNOW MICROAMMETER IS OK)	1	2						

△1 INT MAY BE INTERMITTENT CONNECTION ON EITHER WIRE OR MARGINAL VOLTAGE OFF SENSOR

△2 GROUND FAULT (OPEN)

△3 SHORT TO POWER SOURCE

△4 SYSTEM STABILITY IS ALSO AFFECTED BY THE ENGINE GOVERNOR

TABLE B. MCE100 Standard Units.

OS NUMBER	POWER VOLTS DC	SETPOINT	FEEDBACK KILOHERTZ	FEED FORWARD *	RAMP	OUPUT	CONNECTOR	LOSS OF FEEDBACK
MCE100A1018	14	INTERNAL	1	NONE	SINGLE	V7058	TERM STRIP	YES
MCE100A1026	14	EXTERNAL	1	NONE	DUAL	V7058	TERM STRIP	YES
MCE100A1042	14	EXTERNAL	5	NONE	SINGLE	V7058	TERM STRIP	YES
MCE100A1059	14	EXTERNAL	1	NONE	SINGLE	V7058	TERM STRIP	YES
MCE100A1067	28	INTERNAL	4	NONE	SINGLE	V7058	MS	YES
MCE100A1075	28	INTERNAL	4	NONE	SINGLE	EDC	MS	YES
MCE100A1084	28	INTERNAL	900 HETRZ	NONE	SINGLE	EDC	TERM STRIP	NO
MCE100A1091	14	INTERNAL	1	NONE	SINGLE	EDC	MS	NO
MCE100A1109	14	INTERNAL	.025 - 1	NONE	SINGLE	EDC	MS	NO
MCE100A1117	14	EXTERNAL	1	NONE	SINGLE	EDC	TERM STRIP	NO
MCE100A1125	28	INTERNAL	900 HERTZ	NONE	SINGLE	EDC	MS	NO
MCE100A1133	14	EXTERNAL	1	NONE	2 SEC	EDC	TERM STRIP	NO
MCE100A1141	14	EXTERNAL	3	NONE	SINGLE	EDC	TERM STRIP	NO
MCE100A1156	14	EXTERNAL	1.65	NONE	2 SEC	EDC	TERM STRIP	NO
MCE100A1166	14	EXTERNAL	500 HERTZ	NONE	SINGLE	EDC	TERM STRIP	NO
MCE100B1009	14	INTERNAL	1	425 HERTZ	SINGLE	V7058	TERM STRIP	YES
MCE100B1017	14	INTERNAL	900 HERTZ	425 HERTZ	SINGLE	V7058	MS	YES
MCE100B1025	14	INTERNAL	900 HERTZ	425 HERTZ	SINGLE	EDC	MS	YES
MCE100B1033	14	900 HZ INT	1	1KHZ-5KHZ	SINGLE	EDC	MS	YES
MCE100B1058	14	INTERNAL	900 HERTZ	1KHZ	SINGLE	EDC	MS	YES

* Max Hz. Min Hz = 20% of Max.

Ordering Information

The MCE100A, B PID Controller has been designed to be customized, through a series of optional gain settings, additional features and extra circuit components, to each user's requirements. The specifications listed are for a "standard" controller, but they can usually be modified to fit individual user needs. Consult Danfoss for these customizations. See Table B for standard units.

When ordering a special PID Controller, specify the following information.

SPECIFY	STANDARD	OPTIONS
Supply Voltage	12 Vdc	24 Vdc
Command	Internal	External
Feedback	Pulse Pickup	dc Tach
Maximum Pulse Pickup Feedback Frequency	1 kHz	Variable
Feedforward	No	Yes
Maximum Pulse Pickup Feedforward Frequency	1 kHz to 5 kHz	Variable (450 Hz, 1 kHz)
Output Stage	V7058	EDC
Command Ramp Time (90% of full scale)	4.4 sec	Variable
Ramp Type	Single	Dual
Connector	Screw Terminal	MS or Packard Connector
Cabling	N/A	Feed-forward, Feed-back, Valve, Main Controller

CUSTOMER SERVICE

NORTH AMERICA

ORDER FROM

Danfoss (US) Company
Customer Service Department
3500 Annapolis Lane North
Minneapolis, Minnesota 55447
Phone: (763 2) 509-2084
Fax: (763) 559-0108

DEVICE REPAIR

For devices in need of repair, include a description of the problem, a copy of the purchase order and your name, address and telephone number.

RETURN TO

Danfoss (US) Company
Return Goods Department
3500 Annapolis Lane North
Minneapolis, Minnesota 55447

EUROPE

ORDER FROM

Danfoss (Neumünster) GmbH & Co.
Order Entry Department
Krokamp 35
Postfach 2460
D-24531 Neumünster
Germany
Phone: 49-4321-8710
Fax: 49-4321-871-184