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## **INTRODUCTION**

This manual describes the function, theory of operation, and operating procedures for the System 6 Pressure -dP/dt Module.

Section 1 briefly describes the function of the Pressure - dP/dt Module and its specifications. This section also describes and cross-references each control, indicator, or connector, to a number keyed to the panel illustrations.

Section 2 discusses basic theory, a discussion of transducers and provides a brief description of how the Pressure - dP/dt Module works.

Section 3 provides information about additional equipment necessary to operate the Pressure - dP/dt Module. This section also describes how to connect the transducer and chart recorder, how to calibrate the system, and how to perform an end-to-end test to ensure the system is ready for data collection.

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**1. PRESSURE - dP/dt MODULE**

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**1.1 FUNCTION**

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The Pressure - dP/dt module is a precision pressure transducer amplifier configured to signal condition the output of commonly-used full or half bridge strain gauge pressure transducers. The module supplies a precision and stable 5-volt bridge excitation and an internal reference signal calibration circuit. The amplifier incorporates active filters to set the signal bandwidth from 0 to 100 Hz. In addition, an "averaging" post filter simultaneously provides a MEAN output of the prime signal. The module also provides differentiating signal-processing of the prime signal, outputting a signal whose amplitude is proportional to the rate of change of the prime signal - dP/dt. An internal precision signal generator provides five rate calibration signals. These rate signals are routed to the output and to the differentiating circuits by means of a front panel switch in order to calibrate the output display of recording equipment. Front panel controls allow normalization and setting offsets of the prime signal and the dP/dt signal. A window comparator circuit continuously monitors the output dP/dt signal to insure that the signal level remains within the linear output range of  $\pm 12$  volts. If this limit is crossed in either polarity, an audible alarm will activate.

**1.2 SPECIFICATIONS**

DC Bridge Excitation Voltage	5.000 V $\pm$ 5 mV
DC Bridge Excitation Current	40 mA max

**Pressure Amplifier**

GAIN	182 - 2000 (adjustable)
Input Impedance	200K ohms
Output Voltage	$\pm$ 12V @ $R_L \geq 10K$ ; $\pm$ 10V @ $R_L \geq 2K$
Active Low Pass Filter	$f_c = 100$ Hz (-3dB @ 90 Hz)
Active Averaging Filter (MEAN Pressure Output)	-3dB @ 0.2 Hz
OFFSET Range	$\pm$ 5.2 V (referenced to Output)
Input BALANCE Range	$\pm$ 15 $\mu$ A (summed to transducer output)
CALIB Reference Signal	2.50 mV
Output Polarity	Switchable (+Run, -Run)
Input Receptacle	HIROSE: P/N HR10-7R-6S
Mating Input Plug	HIROSE: P/N HR10-7P-6P

**dP/dt**

Calibration Signal	Trapezoidal -Adjustable amplitude & offset
	100 x P 25 Hz
	50 x P 12.5 Hz
	25 x P 6.25 Hz
	2.5 x P 3.13 Hz
	6.25 x P 1.56 Hz
Differentiator GAIN	0.45 - 5
Differentiator OFFSET	$\pm$ 5 Volts (referenced to output)

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### **1.3 FRONT PANEL CONTROLS**

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**NOTE:** The number preceding each item corresponds to its location in Figures 1 & 2. Error! Reference source not found..

#### **64 FUNCTION SWITCH**

The FUNCTION SWITCH is used to select one of four possible inputs to the signal-conditioning amplifier:

**CALIB** - The precision 2.50 mV is connected.

**ZERO** - The input is shorted.

**-RUN** - A positive going input signal will be negative going at the output (inverting).

**+RUN** - A positive going input signal will be positive going at the output (non-inverting).

#### **66 BALANCE**

The BALANCE control is a 10-turn potentiometer used to inject a balancing current into one output node of the transducer bridge, allowing transducer offsets to be balanced. The range of balance current is  $\pm 15\mu\text{A}$ , which corresponds to  $\pm 2.7\text{mV}$  with a 350 ohm bridge.

#### **63 GAIN**

The GAIN control is a 10-turn potentiometer connected in the amplifier chain that allows the overall gain from input to output to be adjusted over the range of 182-2000.

#### **65 OFFSET**

The OFFSET control is a 10-turn potentiometer used to DC offset the amplifier output over the range of  $\pm 5.2\text{V}$ .

#### **67 dP/dt SWITCH**

The dP/dt SWITCH selects the source input to the differentiator circuit:

**dP/dt** Connects the differentiator to the prime pressure signal. This is the normal position to obtain the rate signal at the output.

**CAL** Activates the internal trapezoidal signal generator from which rate calibration signals are derived and connects this generator to the input of the differentiator.

#### **68 GAIN**

The dP/dt GAIN control is a 10-turn potentiometer that adjusts the amplitude of the differentiated signal (either prime or calibration signal) over a range of 11 to 1. It is used to set the level of the dP/dt signal at the output.

**69 OFFSET**

The dP/dt OFFSET control is a 10-turn potentiometer that adjusts the DC operating point of the dP/dt amplifier. The output can be adjusted (offset) over a range of  $\pm 5.2V$ .

**71 dP/dt CALIB SWITCH**

The dP/dt SWITCH selects the frequency of the internal trapezoidal signal generator. The waveform is symmetrical, continuous and defined by four segments according to the following graph:

50 x P	t = 20 ms, f = 12.5 Hz
25 x P	t = 40 ms, f = 6.25 Hz
12.5 x P	t = 80 ms, f = 3.13 Hz
6.25 x P	t = 160 ms, f = 1.56 Hz
100 x P	t = 10 ms, f = 25 Hz

**70 GAIN**

The dP/dt CALIB GAIN control is a 10-turn potentiometer that adjusts the level of the calibration waveform over an 11 to 1 range.

**72 OFFSET**

The dP/dt CALIB OFFSET control is a 10-turn potentiometer that adjusts the operating point of the calibration generator.

**73 TRANSDUCER INPUT CONNECTOR**

This connector is a miniature, keyed, 6-position, quick-disconnect interface to the transducer cable. Appendix A shows the input connector with pin and key locations.

**Figure 1** Pressure - dP/dt Front Panel

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**1.4 REAR PANEL FOR PRESSURE-dP/dt MODULES**

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**39 PRESSURE OUTPUT (phone jack)**

The high level output signal of the pressure amplifier when the dP/dt SWITCH is in the dP/dt position, and the trapezoidal signal generator output when the dP/dt SWITCH is in the CALIB position.

**40 MEAN PRESSURE OUTPUT (phone jack)**

The high level output of the pressure amplifier after post filtering to provide a MEAN signal.

**49 dP/dt OUTPUT (phone jack)**

The high level output signal at the pressure amplifier after being conditioned by the active differentiator.

**Figure 2** Pressure-dP/dt Rear Panel

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## **2. THEORY OF OPERATION**

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### **2.1 OVERVIEW**

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Pressure transducers - based on the well-established Wheatstone Bridge principal using resistive elements for the bridge legs - are typically a low-level device. Full-scale output signals range can range from less than 1mV to over 10mV. These low level signals must be signal-conditioned by amplification, filtering and offsetting in order to be usable by display, recording and data acquisition devices.

In a typical application the transducer will be selected that is best fitted for a particular pressure-measuring task. Considerations will include the pressure range to be measured, the ease of attachment of the transducer to the pressure source and frequency response. The sensitivity or gauge factor will dictate the gain required to amplify the full scale transducer signal to the full scale display or recording signal. Initial unbalance of the transducer bridge can be compensated with the BALANCE control. Control of output offset and polarity are provided to accommodate output options.

In addition, the module further conditions the signal by filtering and differentiating the prime signal providing simultaneous outputs representing the "MEAN" and dP/dt of the prime signal.

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### **2.2 MODULE FUNCTIONAL DESCRIPTION**

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Figure 3 is a block diagram of the PRESSURE dP/dt MODULE.

Block A is the 5-volt excitation supply whose output is centered around system ground (+2.5V to -2.5 V). The supply is regulated by a precision 2.5 V reference. The regulator is capable of supplying 40 mA bridge excitation current.

Block B is a two-stage, balanced differential to single-ended instrumentation amplifier. This block has a fixed gain of 100. Offset and gain control of the prime channel are implemented in block C, which has an additional gain of 5.23. Block D is a four-pole, active, low pass filter having a gain of 3.84 cornering at 100 Hz. Block E is a two-pole, active, low-pass filter cornering at .2 Hz, providing the "MEAN" output. The prime-channel GAIN control has a range of .091 to 1, so the overall prime-channel gain is:

$$(100) (.091 \text{ to } 1) (5.23) (3.84) = 183 \text{ to } 2008$$

### **Figure 3**

The prime channel OFFSET control is used to DC offset the operating point of amplifier C over the range  $\pm 1.36$  volts. This offset range, referred to the module output, is  $\pm 5.23$  volts. The BALANCE control is used to initially balance the transducer at a reference pressure (usually 0 mmHg). The network is proportioned to sum a current between  $\pm 15$  uA into the output node of the transducer bridge. Using the standard sensitivity of 50 uV/V/cmHg and a bridge impedance of 350 ohms, the BALANCE control would have the capability of balancing a bridge offset of  $\pm 100$  mmHg.

Block F is the active differentiator. It is connected to either the prime channel output or calibration signal generator output using the dP/dt switch. The differentiated signal is further amplified in block G, which incorporates the dP/dt GAIN and OFFSET controls. These controls provide the ability to normalize and calibrate the dP/dt channel to the prime channel and the desired output recorder or data acquisition device. The dP/dt output



is continuously monitored by block H - a "window" comparator whose limits are set at +12V and -12V. If the dP/dt signals exceed these limits, an audible alarm will activate.

Block J is the trapezoidal signal generator used to provide "rate" calibration signals to the dP/dt channel. A five-position dP/dt CALIB switch selects one of five standard rate waveforms. The rate waveforms are timed by a 1MHz crystal oscillator divided by four decade counters to provide a 100 Hz timing signal. Block K incorporates the GAIN and OFFSET controls for the calibration generator. These controls are used to set the calibration waveform amplitude relative to the prime channel.

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**3. FIRST-TIME START-UP AND OPERATION**

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**3.1 EQUIPMENT REQUIRED**

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1. Chart Recorder or Digital Voltmeter
2. Mercury Manometer or other accurate pressure gauge, calibrated in mmHg
3. Pressure source (A 20cc or 30cc syringe can be used.)
4. Pressure transducer
5. Transducer cable terminated with HIROSE HR10-7J-6P (see Appendix)
6. Interconnecting signal cable between PRESS output and Chart Recorder input
7. PVC or surgical tubing for connecting the source, manometer and transducer
8. "T" fitting for tubing

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**3.2 PRESSURE PROCEDURE**

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1. Connect the manometer to the pressure tube using the "T" fitting so that the manometer is measuring the pressure applied to the transducer and connect the input cable to Transducer A.
2. Electrically connect PRESSURE output (see REAR PANEL OUTPUTS for PRESSURE MODULES) to the Chart Recorder or Digital Voltmeter input.

3. Preset the PRESSURE controls as follows:

SWITCH	Zero
GAIN	CW
OFFSET	CENTERED (5 turns from either end)
BALANCE	CENTERED

4. Set up the Chart Recorder so that the pen is in the center of the chart with 0 volts applied. Set the gain on the recorder so a +10 volt signal will run the pen to the top of the chart and a -10 volt signal will run the pen to the bottom.
5. Note the position of the recorder pen with 0 volts applied. Then turn the System 6 power on. Carefully set the OFFSET control so that the pen is in the same position as with 0 volts applied.
6. Move the switch to the CALIB position - the pen should move to approximately halfway between midscale (0 volts) and full scale ( $\pm 10$  volts).
7. Advance the switch to the + RUN position. With 0 mmHg pressure applied, carefully adjust the BALANCE control until the pen is in the center (0 volts) position.
8. Using the pressure source, apply a pressure to the transducer - the pen should move up or toward the +10 volt position. (If the pen moves down, the signal from the transducer is inverted and can be corrected by reversing the signal leads and repeating steps 5-7.)
9. With 0 mmHg applied, readjust the recorder position control until the pen is at the bottom of the chart.
10. Apply a full-scale pressure to the transducer, and adjust the pen position to the top of the scale using either the recorder gain control or the PRESSURE GAIN control. Recheck the 0 position. (Step 9)

11. Apply various pressures between 0 and full scale. The recorder position will track the manometer within the linearity tolerance of the transducer and the accuracy and readability of the chart.

Note: Using a digital voltmeter as the output device will allow more precise setting of the controls.

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### **3.3 dP/dt PROCEDURE**

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The dP/dt signal amplitude is directly proportional to the rate of change of the prime pressure signal. It is important to calibrate the dP/dt channel so that the highest rate signal will not exceed the linear limits of the dP/dt output amplifier.

The internal calibration generator is used to set up the dP/dt channel so that its output is proportional to known calibrated signals. The calibration waveform is as shown in Figure 5. The time intervals are all equal and change with the range switch in accordance with Table 1, and "E out" is adjustable with the CALIB GAIN control.

**Figure 5**

<b>Sw Pos</b>	<b>Time</b>
100 x P	10ms
50 x P	20ms
25 x P	40ms
12.5 x P	80ms
6.25 x P	160ms

**Table 1**

If the GAIN control is set so "E out" is 5 volts and the range switch is set to 50 x P, the slope of the  $t_1 - t_2$  interval is  $\pm 5 \text{ V}/20 \text{ ms}$  and the  $t_3 - t_4$  interval is  $-5 \text{ V}/20 \text{ ms}$ . If this waveform were a prime pressure signal calibrated so that  $100 \text{ mmHg} = 5 \text{ V}$ , then the slopes would reflect rates of  $\pm 100 \text{ mmHg}/20 \text{ ms}$ .

In the CALIB position the above generator waveform is connected to the input of the dP/dt active differentiation. The input and output waveforms are shown in Figure 6.

### Figure 6

If the input waveform was a  $100 \text{ mmHg}/20 \text{ ms}$  signal, then +E would represent increasing  $100 \text{ mmHg}/20 \text{ ms}$  portion, and -E would represent the decreasing  $100 \text{ mmHg}/20 \text{ ms}$  portion. If the slope of the pressure signal were one half as shown by the dotted line, the amplitude of the dP/dt output would halve.

A typical dP/dt setup would consist of choosing a calibration signal slope using the CALIB switch and CALIB GAIN that represents the maximum anticipated slope of pressure gradients on the prime channel. The dP/dt GAIN and dP/dt OFFSET are then used to scale and offset the dP/dt signal to the output device. In the above dP/dt, waveform would represent a scale ranging between  $-100 \text{ mmHg}/20 \text{ ms}$  and  $+100 \text{ mmHg}/20 \text{ ms}$ .

**4. APPENDIX**

**APPENDIX A: TRANSDUCER CABLE**

The PRESSURE -dP/dt module requires a transducer cable having one end terminated with the mating connector for the TRANSDUCER input. The following diagram shows the wire color coding and typical connection to a transducer. This cable is available from TRITON and is PN 200-1930.

Connector - HIROSE P/N HR10-7J-6P

Cable - COONER NMEF 4/26-1938SJ

+ EX	Positive bridge excitation voltage
- EX	Negative bridge excitation voltage
+ SIG	Positive bridge output
- SIG	Negative bridge output

