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INTRODUCTION

This manual describes the function, theory of operation, and operating procedures for the System 6 Differentiator Module.

Section 1 briefly describes the function of the Differentiator 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 input signals and provides a brief description of how the Differentiator Module works.

Section 3 provides information about additional equipment necessary to operate the Differentiator Module. This section also describes how to connect the input signals and the output to a 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.

1. DIFFERENTIATOR MODULE

1.1 FUNCTION

The module generates the first derivative of the input signal, providing an output voltage, the amplitude of which is proportional to the rate of change (instantaneous slope) of the input signal. Typically, the input signal will be a biological signal such as the output from a sonomicrometer of a left ventricular blood pressure signal.

Prior to being differentiated, the input signal passes through a variable gain input amplifier, an offset amplifier and a 4-pole active filter to remove any high frequency noise prior to differentiating. These amplifiers scale and position the input signal on the output device, typically a chart recorder. The calibrated chart recorder trace is then used to calibrate the output of the differentiator. The module provides two outputs: a. The first derivative of the input signal and b. The 'running mean' of the input signal.

The module has a self-contained calibration circuit. An internal precision signal generator provides five different 'rate' (slope) calibration signals. These rate signals are routed to the output and to the differentiating circuits by means of a front panel selector switch in order to calibrate the display on the chart recorder. Other front panel controls make it possible to scale and offset the input signal and the derivative output. A window comparator circuit continuously monitors the output derivative signal to insure that the differentiated output signal remains within the linear output range of $\pm 12V$. If this limit is crossed in either polarity, an audible alarm will activate.

1.2 SPECIFICATIONS
Signal Input Amplifier

GAIN	1 to 11 adjustable
OFFSET	±7.5V (referenced to output)
Output Voltage	±12V @ $R_L \geq 10K$; ±10V @ $R_L \geq 2K$
Active Low Pass Filter	$f_c = 1000\text{Hz}$
Active Averaging Filter (MEAN Signal Output)	-3dB @ 0.2Hz
Output Polarity	Switchable (+) Run or (-) Run
Input Receptacle	HIROSE: P/N HR10-7R-6S
Mating Input Plug	HIROSE: P/N HR10-7P-6P

dx/dt

Calibration Signal	Trapezoidal -Adjustable amplitude & offset
	100 x (X) (25Hz)
	50 x (X) (12.5Hz)
	25 x (X) (6.25Hz)
	12.5 x (X) (3.13Hz)
	6.25 x (X) (1.56Hz)
Differentiator GAIN	0.45 to 5
Differentiator OFFSET	±7.5V (referenced to output)

1.3 FRONT PANEL CONTROLS

NOTE: The number preceding each item corresponds to its location in Figure 1 & Figure 2.

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 1-0.09 (Output “39”, page 9).

65 OFFSET

The **OFFSET** control is a 10-turn potentiometer used to DC offset the amplifier output over the range of $\pm 7.5V$ (Output “39”, page 9).

67 dx/dt - CALIB

The **dx/dt - CALIB** switch selects between the input signal and the calibration waveform. The selected signal is routed to both the Differentiator and the chart recorder:

dx/dt Connects the differentiator to the input signal (**x**). This is the normal operating position to obtain the derivative output.

CALIB Activates the internal trapezoidal signal generator and connects the signal from the “rate” generator to the input of the differentiator and to the primary signal channel of the chart recorder.

68 GAIN

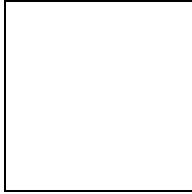
The dx/dt **GAIN** control is a 10-turn potentiometer that adjusts the amplitude of the differentiated signal (either prime or calibration signal) over a range of 1 to 0.09. It is used to set the level of the signal at the dx/dt of the chart recorder.

69 OFFSET

The dx/dt **OFFSET** control is a 10-turn potentiometer that adjusts the DC operating point of the dx/dt amplifier. The output can be adjusted (offset) over a range of $\pm 7.5V$.

71 CALIBRATION SLOPE SWITCH

The **dx/dt - CALIB** 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:



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

70 GAIN

The dx/dt calibrate **GAIN** control is a 10-turn potentiometer that adjusts the level of the calibration waveform over a 1 to 0.09 range. Maximum output 12V peak (Output “49”, page 9).

72 OFFSET

The dx/dt calibrate **OFFSET** control is a 10-turn potentiometer that adjusts the operating point of the calibration generator. Output offset range $\pm 7.5V$ (Output “49”, page 9).

73 TRANSDUCER INPUT

The **TRANSDUCER INPUT** connector is a miniature, keyed, 6-position, quick-disconnect interface to the transducer cable.

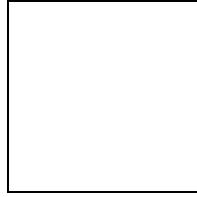


Figure 1 Differentiator Front Panel

1.4 REAR PANEL FOR DIFFERENTIATOR MODULES

39 SIGNAL (x) OUTPUT (phone jack)

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

40 MEAN SIGNAL (x) OUTPUT (phone jack)

The high level output of the pressure amplifier after filtering to provide a 'mean output' signal.

49 dx/dt OUTPUT (phone jack)

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

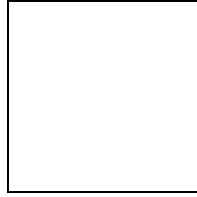


Figure 2 Differentiator Rear Panel

2. THEORY OF OPERATION

2.1 OVERVIEW

In a typical application the input signal (x) will be from a bio-transducer such as a sonomicrometer channel. Control of output offset and polarity are provided to accommodate input signal (x) level and offset voltage. The module further conditions the signal by 1000Hz low pass filtering, differentiating the input signal and providing simultaneous outputs representing the "MEAN" and dx/dt of the input signal.

2.2 MODULE FUNCTIONAL DESCRIPTION

Figure 3 is a block diagram of the DIFFERENTIATOR MODULE.

Offset and gain controls of the prime channel are implemented in blocks A & B, which have gains of 1-11. Block C is a four-pole, active, low pass filter having a gain of 1 cornering at 1000Hz. Block D is a two-pole, active, low-pass filter cornering at 0.2Hz, generating the "MEAN" output. The primary channel GAIN control has a range of 1-0.09.

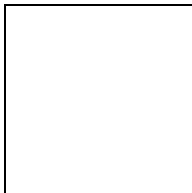


Figure 3

The input signal **OFFSET** control is used to DC offset the operating point of amplifier B over the range $\pm 7.5V$.

Block E is the active differentiator. Its differentiator circuit input is connected to either the output of the primary channel or the trapezoid calibration signal generator as selected by the **dx/dt-CALIB** switch.

The differentiated signal is further amplified in block F, which incorporates the dx/dt **GAIN** and **OFFSET** controls. These controls make it possible to scale and calibrate the dx/dt channel output to the derivative channel of the chart recorder.

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

Block H is the calibration signal generator used to provide "rate" or slope calibration signals for the dx/dt channel. A five-position dx/dt **CALIB** switch selects one of five standard rate waveforms. The "rate" waveforms are timed from a 1MHz crystal clock oscillator, the output of which is divided to provide a 100Hz timing signal. Block J incorporates the **GAIN** and **OFFSET** controls for the calibration generator. These controls are used to set the calibration waveform amplitude relative to the primary channel when calibrating the derivative trace on the chart recorder.

3. FIRST-TIME START-UP AND OPERATION

3.1 EQUIPMENT REQUIRED

1. Chart Recorder or Digital Voltmeter
2. Input cable terminated with 1/4" phone plug
3. 1/4" Phone plug signal cable between output and chart recorder input
4. Low frequency signal generator, sonomicrometer, etc.

3.2 DIFFERENTIATOR PROCEDURE

In order to calibrate the Differentiator output, it is first necessary to calibrate the signal, (x), to be differentiated on the chart recorder (or equivalent). Once this primary channel is calibrated, the chart recorder is then used to calibrate the derivative, (dx/dt). After the chart recorder is calibrated, the chart gain and offset controls should not be adjusted as this will change the calibration.

1. Connect the signal to be differentiated to the front panel input connector using a cable terminated with a 1/4 inch (6mm) phone plug, "73", page 7.
2. Connect cables from the back panel to the chart recorder using cables terminated with 1/4 inch phone plugs. Connect the signal (x) cable to "39", (**EKG**). Likewise connect the Differentiator Output (dx/dt) cable to "49", (**FLOW OUT**). If a Mean Output is desired a cable should be connected to "40", (**SONO OUT**).
3. A typical application of the Differentiator is to differentiate a sonomicrometer output signal in order to develop a "velocity of shortening " signal. Connect the input of the Model 209 Differentiator to the output of the sonomicrometer channel. The sonomicrometer signal must pass through the Model 209 before going to the chart recorder in order to establish calibration values.
4. Turn **GAIN** control in the upper portion of the front panel (SIGNAL (X)) a full turn counter clockwise.
5. Temporarily short the input signal to the chart recorder to ground potential. With the chart recorder input grounded, adjust the chart recorder offset control so that the pen of the chart recorder is centered on the chart paper. Remove the short from the chart recorder input and re-connect the cable from the Differentiator to the chart recorder.
6. Short the input signal to the Differentiator to ground potential. Use the **OFFSET** control in the upper portion of the Model 209 panel to re-center the chart recorder pen.
7. Perform a Sonomicrometer Calibration as described in Section 3.4.3 of the Sonomicrometer Manual. Use the Gain and Offset controls of the Sonomicrometer module to position the waveform on the chart paper. Use the Gain and Offset of the chart recorder to make fine adjustments. It should be necessary to use the GAIN and OFFSET controls of the Model 209 Module only if the sonomicrometer and chart recorder controls do not have sufficient control to place the Sonomicrometer Calibration waveform on the chart. The chart recorder is now calibrated in units of "mm".

CAUTION: DO NOT ADJUST THE CHART RECORDER CONTROLS AFTER THIS PROCEDURE AS IT WILL CHANGE THE CALIBRATION.

3.3 dx/dt PROCEDURE

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

The internal calibration generator is used to set up the dx/dt channel so that its output is proportional to known calibrated signals on the primary channel. The calibration waveform is shown in Figure 5. The time intervals are all equal and change with the range switch in accordance with Table 1 and "E out", figure 6, is adjustable with the calibration GAIN control.

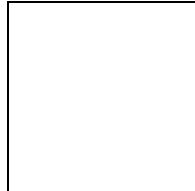


Figure 5

Switch Position	Time
100 x (X)	10ms
50 x (X)	20ms
25 x (X)	40ms
12.5 x (X)	80ms
6.25 x (X)	160ms

Table 1

If the **GAIN** control is set so "E out" is 5V and the range switch is set to 50 x P, the slope of the $t_1 - t_2$ interval is $\pm 5V/20ms$ and the $t_3 - t_4$ interval is $-5V/20ms$. If this waveform were a sonomicrometer signal calibrated so that 10mm = 5V, then the slopes would reflect rates of $\pm 10mm/20ms$ or a velocity of $\pm 500mm/second$.

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

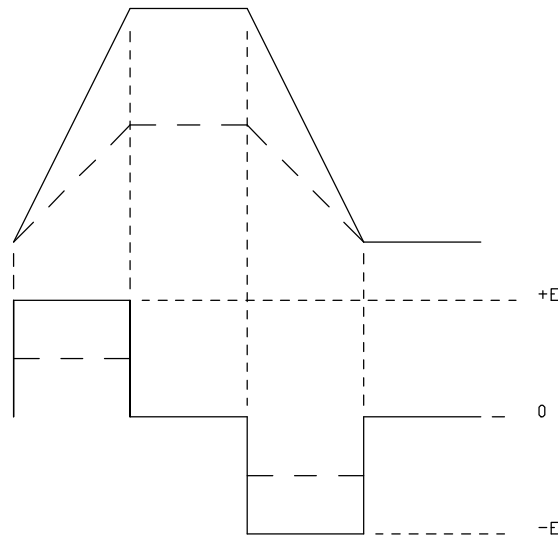


Figure 6

If the input waveform was a 10mm/20ms signal, then +E would represent increasing 10mm/20ms portion, and -E would represent the decreasing 10mm/20ms portion. If the slope of the pressure signal were one half as shown by the dotted line, the amplitude of the dx/dt output would halve.

A typical dx/dt setup would consist of choosing a calibration signal slope using the **CALIB** position and calibrate **GAIN** that represents the maximum anticipated slope of pressure gradients on the prime channel. The dx/dt **GAIN** and dx/dt **OFFSET** are then used to scale and offset the dx/dt signal to the output device.

8. Place the **dx/dt - CALIB** switch in the middle section of the 209 Module Front Panel in the **CALIB** position. This causes the trapezoid calibration to be sent to the Primary channel on the chart recorder. Do not adjust the controls on the chart recorder as this will

disturb the calibration. Instead, use the Trapezoid Generator **GAIN** and **OFFSET** controls in the bottom section of the Model 209 front panel (**dx/dt - CALIB**) to adjust the trapezoid amplitude and offset so that the trapezoid waveform appears on the sonomicrometer channel. Adjust the bottom section **GAIN** and **OFFSET** controls so that the trapezoid wave swings between the High and Low Calibration levels (see Figure 4 in the Sonomicrometer Manual). When correctly positioned, the trapezoid will just touch the High Cal swinging up and just touch the Low Cal line swinging down. In this example, the trapezoid would be swinging a voltage equivalent to a 10mm output change from the sonomicrometer.

9. The last step is to calibrate the dx/dt output to the chart recorder. Place the dx/dt Calibration switch in the “**100 x (x)**” position. Use the **GAIN** and **OFFSET** controls in the center section of the Model 209 Front Panel to position the derivative signal on the second channel of the chart recorder. The waveform should swing equally on both sides of the centerline of the trace. Adjust the amplitude of the derivative output so that it deflects across the entire chart, i.e. +/- 5 divisions.

This corresponds to a deflection of 10mm times 100 or 1000mm/second. If this calibration is too high, then repeat Step 9 with the calibration selector set to “**50 x (x)**”, etc.

10. Return the dx/dt selector switch in the middle section from **CALIB** back to the **dx/dt** . This completes the calibration of the Differentiator.

CAUTION: Changing any of the controls on the Differentiator Module, Chart Recorder or the Sonomicrometer will change the calibration and the above procedure must be repeated.