Duratech

Custom Scientific Controls and Equipment

Viscometer DV-8

User's Manual

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LIMITED WARRANTY - DURATECH ELECTRONIC FALLING BALL VISCOMETER

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3. Modification or misuse by the Purchaser.
4. Operation outside the environmental and electrical specifications for the product.
5. Improper or inadequate site preparation.
6. Purchaser induced contamination or leaks.

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Introduction

This manual was revised for DV series Viscometers produced after July, 2004.

We believe you will be pleased with your new DV Series Viscometer. It was originally designed for one of the largest chemical companies in the world. Their enthusiastic reception of this well designed instrument has prompted us to offer it to the entire chemical industry. You have purchased an instrument that has proven to be accurate, reliable and easy to use.

If you do have a problem or question, please contact us. We are here to help you make the best use of the instrument.

The DV Series Viscometers consist of three models. The DV-1 includes the Controller Console and a single-tube Test Station. The DV-4 includes the Controller Console and a four-tube Test Station. The DV-8 includes the Controller Console and an eight-tube Test Station. The Controller Console contains the keypad, display and electronics. The Test Station is usually immersed in a user-supplied oil bath and contains the sensors and the sample tube holders.

The DV-1 can test one sample at a time. The DV-4 can test up to four samples simultaneously. The DV-8 can test up to eight samples simultaneously and each of the two Test Stations can be placed in separate oil baths in order to test samples at two different temperatures.

To make a measurement, the operator places the sample fluid in a plastic sample tube and inserts the tube into the Test Station. The operator then places the ball guide on the sample tube and drops a ball through it.

As the ball falls, it is automatically detected and the fall is timed. An audio signal then alerts the operator when the measurement is completed.

The operator can then read the results directly in poise or centipoise, and has the option of sending the results to the optional printer or to a user-supplied computer.

Specifications

Viscosity Range: 3 to 50,000 poise

Test Time: approximately one minute per 1,000 poise

Accuracy: better than 1%

Repeatability: +/- 0.75%

Oil Bath: The Test Station can be immersed in either silicone oil or mineral oil.

Temperature Range, Test Station: -20 deg C to 100 deg C

Temperature Range, Controller Console: 0 deg C to 40 deg C

Input Voltage: 85-265 VAC, 47-440 Hz, 20 Watts.

Fuse: 2.0 A

Physical Dimensions:

Controller Console: 11.25"D X 10"W X 5.5"H

Single-Tube Test Station: 5.5"D X 5.5"W X 10"H

Four-Tube Test Station: 8.5"D X 8.5"W X 12"H

Eight-Tube test Station: 8.5D X 16.5"W X 12" H

Sample Tube: polyethylene, 1.260" ID, 150 ml volume

Ball: steel, 0.375" dia

RS-232 Interface:

Baud Rate: 1200, 2400, 4800, and 9600.

Character Size: 8 bits. The 8th bit is a space. No parity bit.

Setup

The viscometer is available in several models, and each model has some optional functions. Setup conditions must be programmed to make your particular model function correctly with your particular options. To get into the setup mode, press the "CLR" key, and the "*" key twice. Then simply answer YES or NO to the questions on the display. You have a choice of:

1, 4, or 8 sample holders
Maximum length of time allowed for a ball drop. 10 to 90 minutes.
Host computer connection
Serial printer option
Baude rate selection, 1200, 2400, 4800, or 9600 baude

When finished, press CLR.

Installation

Place the Test Station(s) in an oil bath(s). The oil level should be just about even with the top cover. (The oil just covering the openings of the sample holders.) Level the Test Station using the four leveling screws and the bubble level.

Place the Controller Console next to the oil bath. Plug the first Test Station into the lower connector on the back of the Controller Console. If a second Test Station is being used, plug it into the upper connector.

If the optional printer or a computer is being used, connect it to the RS-232 port on the back of the Controller Console.

The Viscometer uses anuniversal instrument power cord. You may have to obtain one compatible with the power outlets in your country.

Plug the Controller Console in and turn it on.

Operation

Keypad

The keypad is used by the operator to enter data and select the desired function. Keys "0"-"9" are used to enter sample holder numbers, identification (ID) numbers, and factors. The keys labeled "CLR" and "FTR" stand for CLEAR and FACTOR respectively.

Test Station

There are either one, four, or eight holders for test samples depending on the model. Each holder has its location marked on the cover. The examples given in this manual are for the DV-8, which can test up to eight samples simultaneously.

Power-on

At the power on condition, a message is displayed for 5 seconds. If, at this time, you press the * key, the display will indicate where you can obtain customer service and assistance. Press the CLR key to remove the message.

Standby

STANDBY is the usual mode of the instrument when it is on but not in use. When the instrument is first turned on it automatically goes into STANDBY. All test information (except for the factors and setup conditions) are set to zero when entering STANDBY. The Viscometer may be returned to the STANDBY mode at any time by pushing the "CLR" key.

The display will show:

-STANDBY-

RUN = Start test
FTR = Set factor

If the operator wants to examine and/or change the factors, he pushes the "FTR" key (see "Factor" for more information.) If the operator wants to begin a test, he pushes the "RUN" key (see "Test" for more information.)

Factor

Background and Theory

The Viscometer measures the fall-time of the ball as it drops at a constant velocity between two sensors spaced 2.86 inches apart. During the timing period, a counter is incremented at 2400 counts per second. When the timing stops, the counter contains a number that is proportional to viscosity. This number must then be multiplied by a constant, or conversion factor, in order to provide a result in meaningful units.

The conversion factor used depends on the density of the sample being tested and must be changed when a sample with a different density is to be tested (see "How to Calculate the Factor" and "How to Examine and/or Change the Factor" for more information.) The last factor used with each holder position is retained, even when the unit is turned off or unplugged.

The timer is a 24 bit binary counter. The count and factor are each stored in 24 bit binary registers. When the two are multiplied, the result is a 48 bit binary number. The least significant 24 bits are discarded, which is the equivalent of dividing by 16777216 (2^24.)

Hence:

number displayed = 2400(t)(factor)/16777216

Where:

t = time, in seconds

For example, to display the result in units of milliseconds of fall time:

Let:

number displayed = 1000(t)

The equation becomes:

1000(t) = 2400(t)(factor)/16777216

Solving for the factor:

factor = 6,990,506.67

The factor is then rounded off and a leading zero is added to make it eight digits:

factor = 06990507

How to Calculate the Factor

To determine the factor for units of centipoise use:

$$\text{factor} = C(7.786 - Ds)$$

Where:

C	=	1985100
Ds	=	density of test sample, in grams per cubic centimeter

The constant C was determined by calibrating the instrument using the physical dimensions (see "Calibration, Using Physical Dimensions" and "Calibration, Using an Oil Standard" for more information.)
To get results in poise, divide the factor by 100.

Round off the answer to the nearest whole number. The factor must have eight digits, some of them may be leading or trailing zeros. The maximum allowable number is 16777215. For maximum resolution, units of centipoise are recommended, especially for viscosities under 300 poise.

The density of the test sample should be significantly less than the density of the steel ball (say, less than 5.0.) Many liquids have a density near that of water, 1.0. For a density near 1.0, a density error of 1% would contribute 0.15% to the measurement error.

How to Examine and/or Change the Factor

To examine or change the factor, the Viscometer must first be in STANDBY. Press the "FTR" key. Suppose the current factor for holder # 1 is 12345678. The display will show:

Holder : 1
Factor: 12345678

Change? YES/NO

Pressing the "CLR" key returns the Viscometer to STANDBY. Pressing the NO key increments to the next holder and displays its factor. If you press the yes key, the display will show:

Holder : 1
Factor : 12345678

New : _

Use keys "0" to "9" to enter the new factor. Suppose the new factor is "11223344." When all eight digits are entered, the display will show:

Holder : 1
Factor : 11223344

Change? YES/NO

If an error is made when entering the factor, just enter it again. When it is correct, press the "NO" or "CLR" key. It will increment to the next holder or return to STANDBY.

Test

Before testing, the samples should be placed in the holders. They should be well seated and left there for a time to allow them to come to the proper temperature.

To begin testing, press the "RUN" key while in STANDBY. If you have a printer option, or are transmitting results to a host computer, you will need to enter a 4 digit ID number. The display will show:

Holder : 1
ID : 0000

Change? YES/NO

After entering the 4 digit ID number, the display will appear as above, except with the ID number that you just entered. Pressing "NO", will cause it to increment to the next holder. Press "RUN", when you have entered all the ID numbers. the display will then show:

Balls (....)

Drop balls now !

If the instrument was setup without the printer option, or to transmit the results to a host computer, the instrument would go directly to the above message and skip the proceedure to enter the ID numbers.

Drop a ball into each of the samples to be tested. Use the ball guide to center the ball. Take care not to disturb a sample once the ball has been dropped into it. When the first ball passes the upper sensor, testing begins. The display will show:

balls (1.......)

RUNNING TEST

Testing ends when all of the balls that have been dropped have passed through the lower sensors. Hence, the last ball must be dropped while at least one of the preceding samples is still under test. Completion of the test is indicated by an audible signal. For an eight position holder stand, with the printer option, the display will show:

-TEST COMPLETED-
Holder 1 ID 1234
Result=12345678
Print? YES/NO

Pressing the "YES" key will cause the result to be sent to the printer, Pressing the "NO" key, will cause it to increment, and display the result from the next holder.

If the proper factor is used, the result will be displayed in centipoise. When all of the results have been printed or transmitted, press the "CLR" key to return to STANDBY. Any result can be displayed until the "CLR" key is pressed. Pressing the "CLR" key erases the results and returns the Viscometer to STANDBY.

Transmitting the Result to a Computer, Additional Information

Suppose, at setup, you have selected the option to transmit thr results to a host computer, and the display shows the following:

-TEST COMPLETED-
Holder 1 ID 1234
Result = 12345678
Transmit? YES/NO

Pressing the "YES" key will cause the results to be transmitted to a host computer. (Refer to the section "Serial Interface" for the format of the transmitted results.)

Calibration

Calibration, Using Physical Dimensions

The instrument was calibrated using the physical dimensions with the proper mathematical treatment. (Reference, Paint Flow and Pigment Dispersion by T.C. Patron, published by John Wile & Sons. Also, ASTM Standard D 1343-86.)

According to Stokes' Law:

$$V = 100(t/L)(2/9)(r^2)(Db-Ds)(g)(Wcf)$$
$$= 21800(t/L)(r^2)(Db-Ds)(Wcf)$$

Where:

V	=	viscosity in centipoise
t	=	time in seconds
r	=	radius of steel ball in centimeters, 0.47625 cm
Wcf	=	wall correction factor
Db	=	density of ball, 7.786 grams/cm^3
Ds	=	density of test sample
L	=	length of ball drop in centimeters, 7.2644 cm
g	=	acceleration of gravity, 981 cm/second^2

$$Wcf = 1-2.104(d/D)+2.09(d/D)^3-0.95(d/D)^5$$

Where:

d	=	diameter of ball, 0.375 inches
D	=	diameter of sample tube, 1.235 inches

Therefore:

$$Wcf = 0.417193$$

and

$$V = 283.964(t)(Db-Ds)$$

To get the number displayed in terms of viscosity let:

number displayed = V

$$2400(t)(factor)/16777216 = 283.964(t)(Db-Ds)$$

Solving for the factor:

$$\text{factor} = 283.964(Db-Ds)16777216/2400$$
$$= 1985100(7.786-Ds)$$

This number, 1985100, is the calibration constant, C.

Calibration, Using an Oil Standard

The Viscometer has already been calibrated using the physical dimensions. It is also possible for the user to re-calibrate it with a standard silicon oil of known viscosity. Utmost care should be taken as any error in the calibration will result in measurement errors later.

First, enter a factor of 16777215. (Refer to "How to Examine and/or Change the Factor") This factor is somewhat arbitrary, but it provides the maximum resolution. Next, use the standard silicon oil and proceed as if measuring viscosity. Several measurements should be taken and the results averaged.

Calculate the factor as follows:

$$\text{factor} = \frac{16777215(\text{known viscosity of standard silicon oil})(7.786-Ds)}{(\text{averaged results from standard silicon oil})(7.786-Do)}$$

Where:

Do	=	density of the oil standard
Ds	=	density of the sample with unknown viscosity

The factor must be rounded off to the nearest whole number and leading zeros added, if necessary, to make it 8 digits.

Accuracy

Accuracy is better than +/- 1.0% and repeatability is better than +/- 0.75%

The Falling Ball Viscometer is an absolute viscometer, and is often used to calibrate other viscometers. It is calibrated by using Stokes' law and physical dimensions and constants (Refer to Calibration, Using Physical Dimensions.)

The combined error traceable to the Viscometer tolerances is about +/- 0.65%. The largest single source of error is the tolerance of the diameter of the sample tube, which is +/-0.005", resulting in a maximum contribution of +/- 0.5% to the measurement error.

The Viscometer is best suited for Newtonian liquids. It can also test non-Newtonian liquids, but at a specific shear rate given by the following expression:

$$\text{sheer rate} = \frac{27(\text{ball velocity})}{8\ (\text{ball radius})}$$

To achieve maximum accuracy, the operator should observe the following:

1. Maintain the samples to be tested at a constant temperature in an oil bath. The oil level should be at least slightly above the level of the liquid in the sample holder tubes.

2. The balls should be kept clean, and at the same temperature as the samples. A good way to do this is to keep a supply of balls in an extra sample tube which is immersed in the oil. Do not use one of the test positions for this because it will interfere with measurements.
3. The device used to pick up the ball should be kept at the same temperature as the samples.

4. Use the ball guide.

3. Ensure the correct factor is used for the density of the sample being tested.

4. Make sure that the test station is level before using it.

5. For best results, the ball must fall a distance in the liquid and reach a constant velocity before it passes through the first ball sensor. The lower the viscosity, the more distance is needed. Thus, it is important to completely fill the sample tube with the sample. (A further refinement is to fill the tube so that the ball can drop a distance in air and achieve a velocity that is nearly correct before it enters the sample. At 300 centipoise, and with the ball guide supplied, this distance is 0.52 inches from the top. With higher viscosities, say above 1000 centipoise, it is not as important, and maximum accuracy can be achieved with the tube filled to 0.5 to 1.5 inches from the top.

Theory of Operation

Refer to DV-BLOCK, DV Block Diagram, and DV-WAVE, DV Waveforms. The heart of the instrument is the sensing coils, which detect the ball. There is an upper and lower set of sensing coils for each holder. The Viscometer measures the fall time of the ball, from the center of the upper sensing coil, to the center of the lower sensing coil.

The sensing coils are excited by a 5KHz signal. A voltage of equal amplitudes, but opposite phases, is applied to each terminal of the sensing coils. Thus, if the circuit is balanced, zero volts (a null) appears at the centertap of the sensing coils. When the ball enters the upper sensing coil, it alters the balance, and a voltage appears at the centertap. The amplitude and phase of this voltage depend on the position of the ball. When the ball reaches the center of the sensing coil, the centertap is again at a null.

The centertaps of the upper and lower sensing coils go to a differential amplifier. The amplifier has adjustments to compensate for any unbalance in the circuit (in the absence of the ball.)

A discriminator converts the output of the amplifier to DC. It does this by switching the gain from +1 to -1 at a rate of 5KHz, synchronously with the excitation signal. The DC signal then goes to a low pass filter, with a cutoff frequency of about 350 Hz. The output of the filter then goes to a comparator. It is converted to a logic signal and sent to the microcomputer.

The microcomputer is based on the 8031 microprocessor. It times the fall time of the ball and multiplies the fall time by the factor. It also scans the keypad, drives the display and speaker, and communicates to a printer or computer via the RS-232 interface.

Serial Interface

Type: RS-232

Baud Rates: 1200, 2400, 4800, and 9600

Character Size: 8 bits. The 8th bit is a space. No parity bit.

Format of Data Transmitted:

<4 CHARACTER ID#> <space><8 CHARACTER RESULT> <CR>

The most significant characters are transmitted first. If the result is zero, nothing will be transmitted.

Format of Data Received:

After transmitting the data, the Viscometer expects an answer within 10 seconds. If the data is accepted, the printer or computer should answer with:

<ACK> <CR>(optional)

If the data is not accepted, the printer or computer should answer with:

<NAK> <CR>(optional)

Connector:

A 9 pin sub-min D female connector is used. The pin assignment is:

PIN	USE
2	TDX (transmit)
3	RDX (receive)
4	DTR (Data Terminal Ready, always high)
5	Signal Ground
6	DSR (Data Set Ready)

Adjustments

To reach the adjustments, remove the top cover. There are two screws on the bottom which hold the cover. Remove them, and the top cover can be lifted.

Contrast

The adjustment is located on the VEC2 board, near the front left. To adjust, view the display from the usual viewing angle and adjust the CONT (P1) potentiometer for best contrast.

Oscillator Frequency

The oscillator frequence is fixed at the factory. It can not be not be changed by the customer. However, if a problem is suspected, it can be checked. It should be 5Khz.

Oscillator Amplitude and Gain Balance

These adjustments are all located on the VEC2 board. Please be aware that these adjustments on the original board, as well as any spare, have been factory adjusted.

Oscillator Amplitude

With an oscilloscope, observe the waveform at the junction of D3 and D4 on the VEC2 board. (Refer to page 21) With the Viscometer in STANDBY, press the "*" key. The display will show:

Hardware setup
(optional)
Push * again for
software setup

Turn the OSC pot until the amplitude is 13V P-P or less. Now turn the pot until the peaks of the sine wave start to clip, at about 15V P-P. The flat top on the sine wave should be about 35-40 microseconds wide.

Gain Balance

This adjustment is made in order to obtain equal amplitudes at the output of U12 and U13, the power amplifiers. Use a two channel oscilloscope and select the "ADD" function of the scope. The display should show the same message as above. Adjust for a null. After a null is reached, it is advised that scope channels be swapped to ensure that they both have the same gain.

Sine and Cosine Null, and Phase

The Sine and Cosine Null, and Phase adjustments are located on the 4AD1 board(s). Although factory pre-adjusted, they will have to be re-adjusted if the board, or one of the sample holders is replaced.

Before adjusting, remove all sample tubes from the holders. Connect the ground connection of the oscilloscope to the ground test point on the upper 4AD1 board. (See page 22). Connect the trigger input of the scope to one end of L2 on the VEC1 board (See papge 21). (The scope test probe is moved to the various test points.) Turn on power, press the keys "CLR" and "*". The display should be showing:

Hardware setup.
(optional)
Push * again for
softeware setup

Sine and Cosine Null

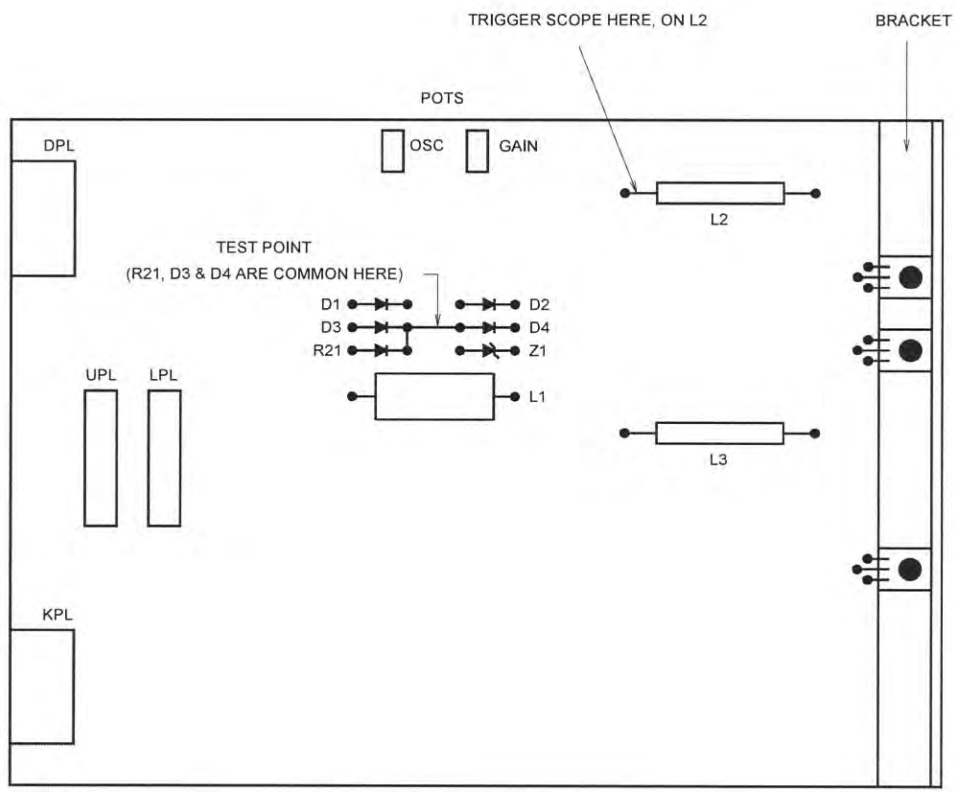
Depending on the model number there are up to eight channels. The DV-1 has one channel on one 4AD1 board. The DV-4 has four channels on one 4AD1 board. The DV-8 has four channels on the first 4AD1 board and four channels on a second 4AD1 board. Each channel had an adjustment for sine and cosine null. The null is observed at TP1 of each channel. Starting with channel one, adjust P1 and P2 for a null at TP1, channel 1. (Leave the phase adjustment , P3 for later.) A null of 50 millivolts P-P is adequate.

Phase

There is just one phase adjustment on each 4AD1 board. Its purpose is to cause the discriminators to switch gain from +1 to -1 at the proper instant. To make the adjustment, the the display must be showing the same message as above. Connect the test lead of the scope to TP2, channel 1. Put a ball in an empty sample tube and lower the tube into the holder. (Sample holder #1, or #5) Lower the tube until the ball is in the center of the upper sensor and a null is observed on the scope. Now move the tube up and down and adjust the phase pot according to the TP2 waveforms shown in DV-BLOCK, DV Block Diagram. If you have 8 sample holders, repeat the adjustment for the other 4AD1 board.

Troubleshooting

Symptom	Possible Cause
Power light not lit, display blank, and no response to	Viscometer not plugged in, fuse blown, or bad power keypad. supply.
Power light lit, but nothing on display and no response to keypad.	Check power supply and +5V regulator on VEC1 board.
Display active but no response to the keypad.	A noise pulse might have caused the microcomputer to malfunction. Reset by turning it off for 2-5 seconds.
Responds to some keys, but not others (no beep = no response.)	Faulty keypad or connection.
Display shows: TEST ABORTED possible error Press CLR for machine restart or -TIME LIMIT-	Ball was dropped before pushing the “RUN” key. The cable to the sample holder, disconnected misaligned, or a bad cable connection Bad 4AD1 board, sine and cosine null misadjusted. Several balls in the bottom of the sample tube.



REVISIONS	
080304	UPDATE

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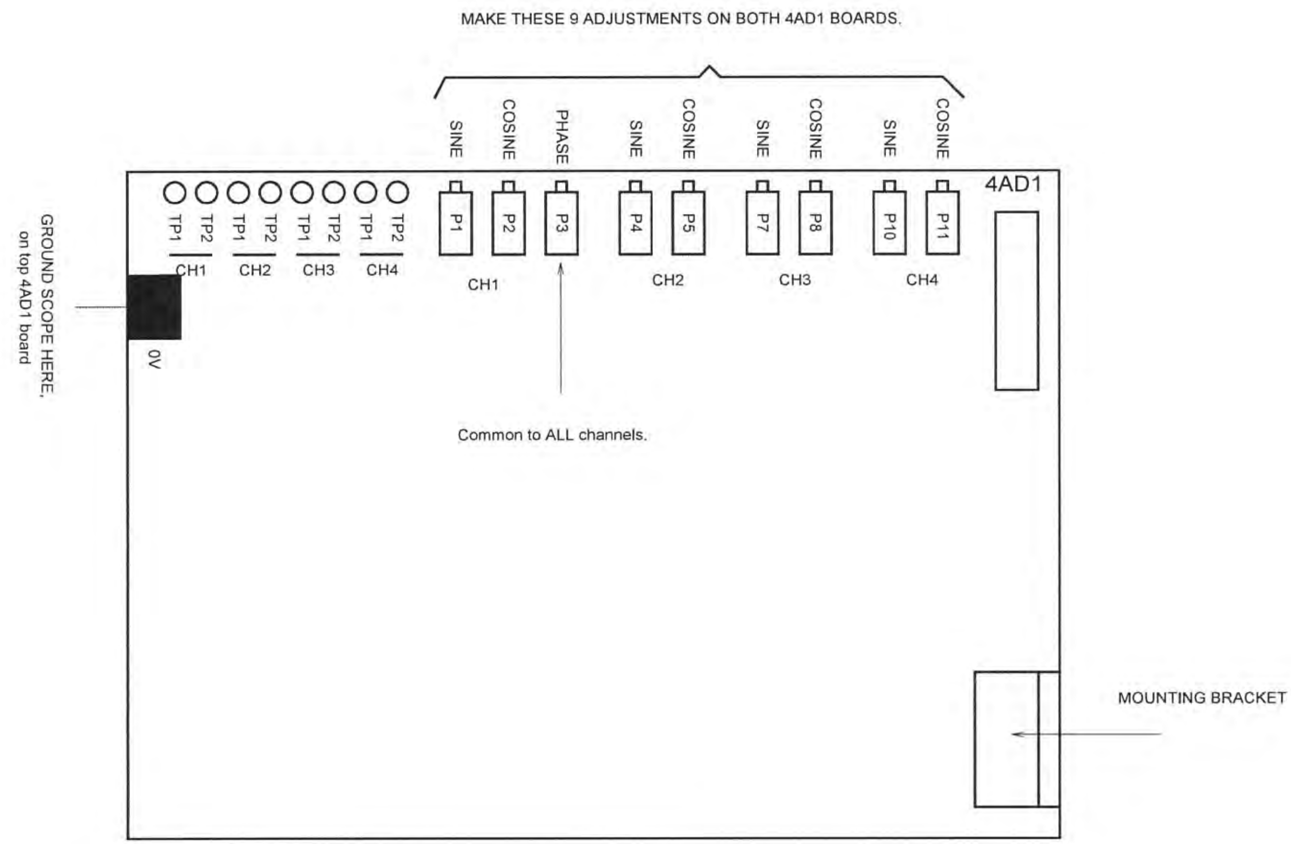
DRAWING NO. DV-ADJ1		PG 1 OF 1



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TITLE 4AD1 Ajustment Locations		
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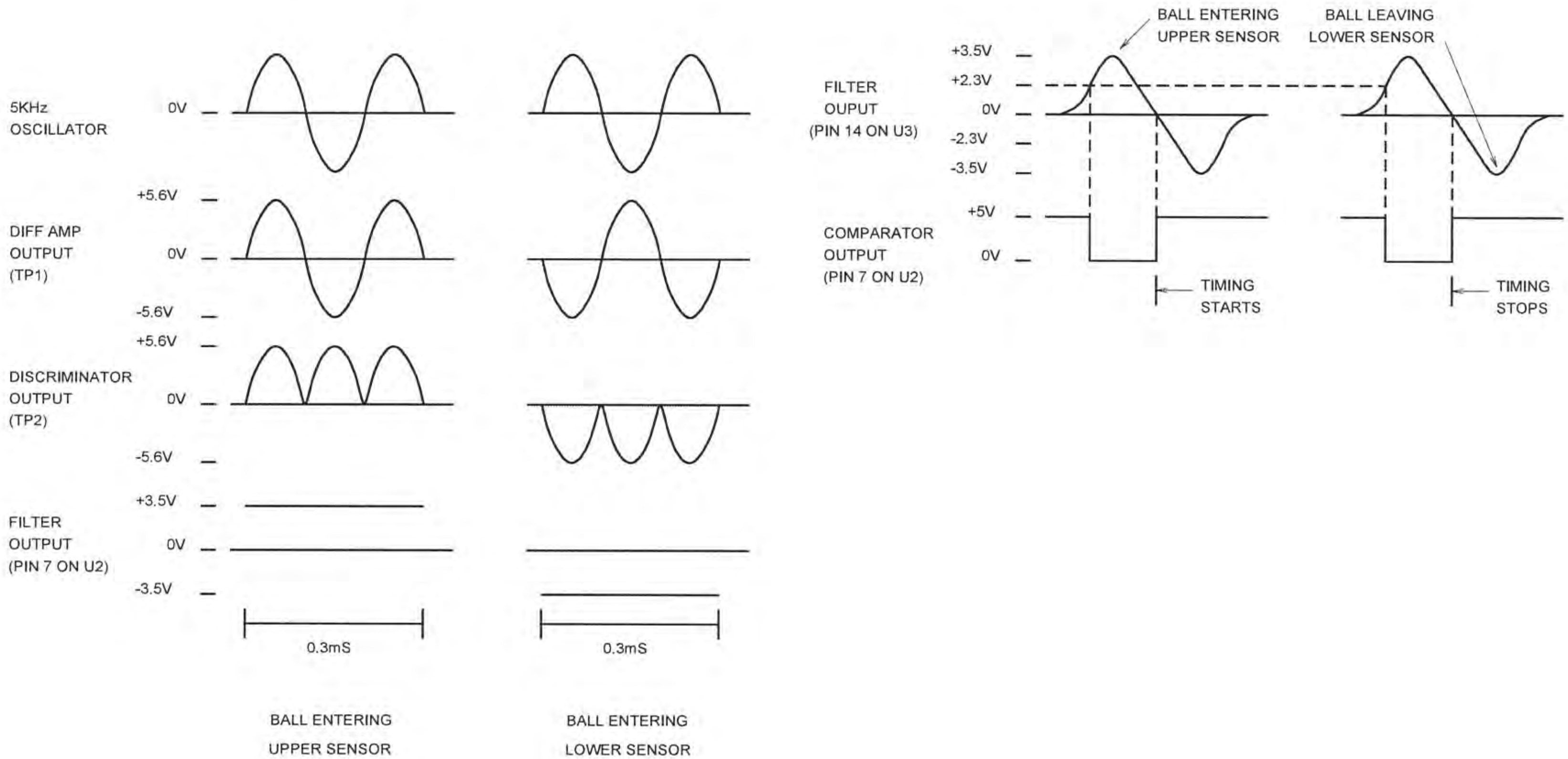

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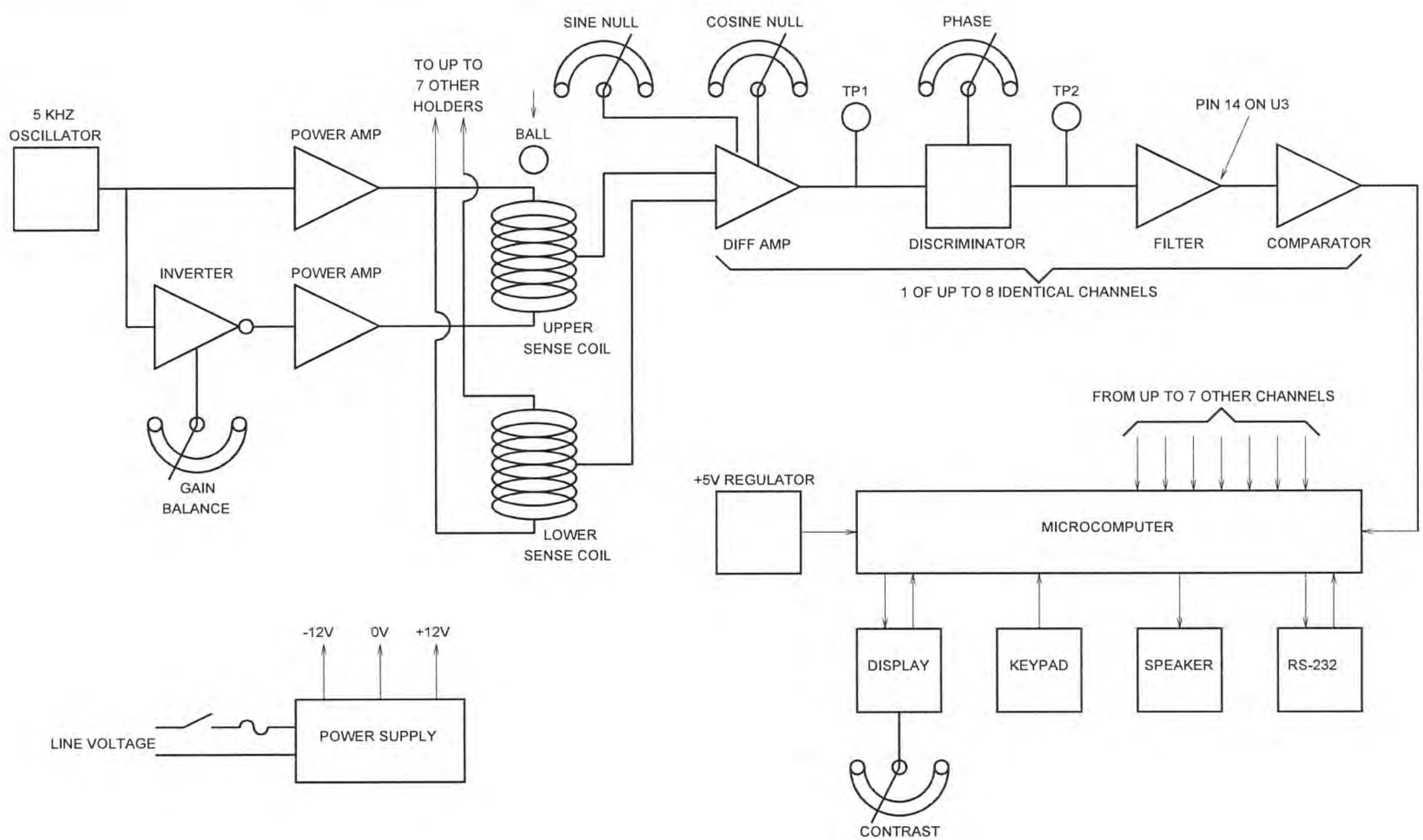

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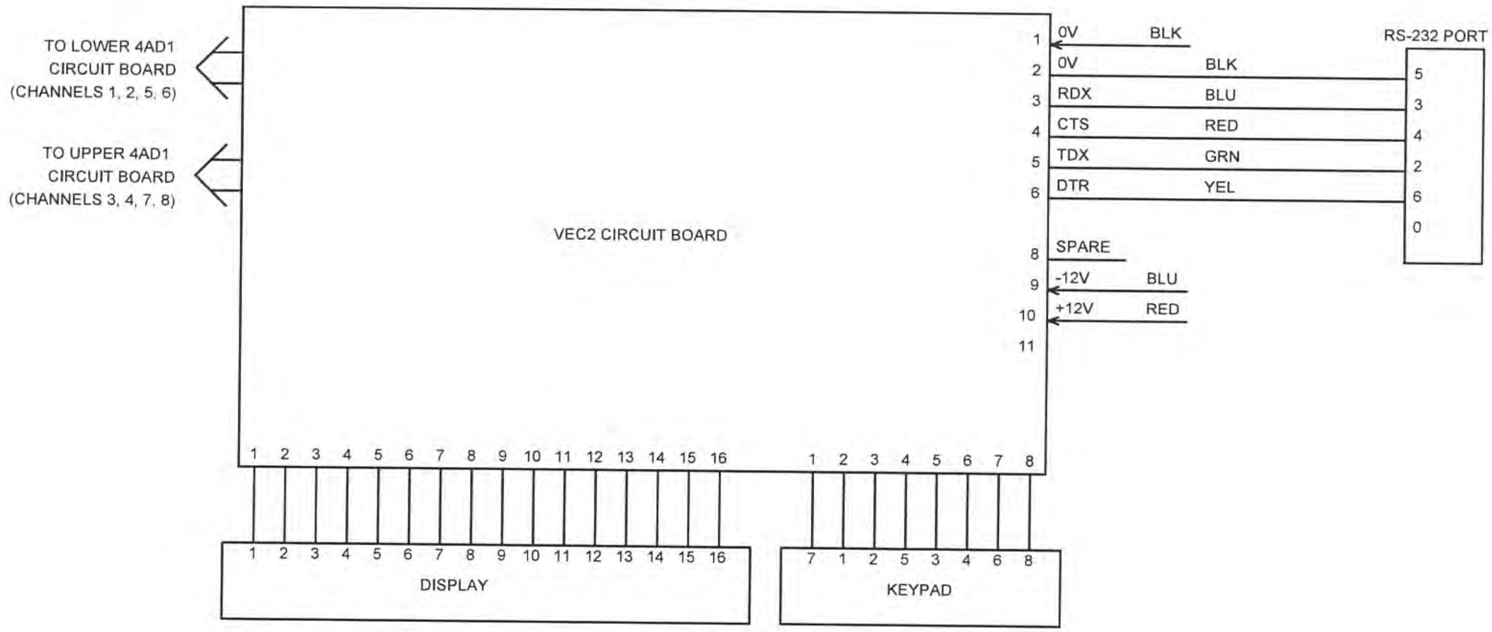

LEGEND			

REVISIONS	DVELEM1
080304	UPDATE
081004	REMOVED CONTRAST ADJUSTMENT

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TITLE VISCOMETER ELEMENTARY		
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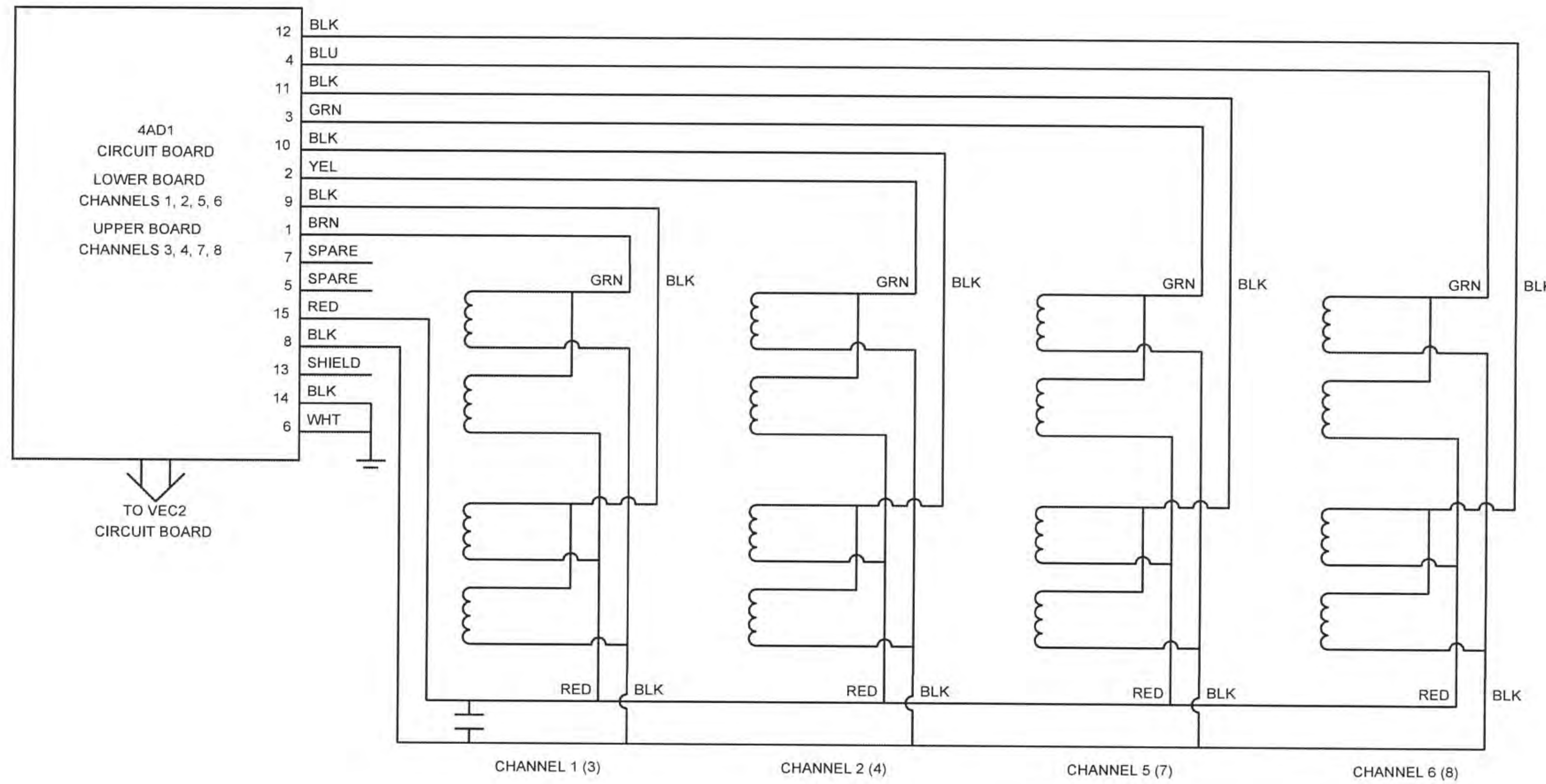
DRAWING NO. DV-ELEM		PG 1 OF 2



LEGEND		

REVISIONS	DVELEM2
080304	UPDATE

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TITLE VISCOMETER ELEMENTARY

DATE	REV	DRAWN/APPROVED
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DRAWING NO. DV-ELEM

PG 2 OF 2