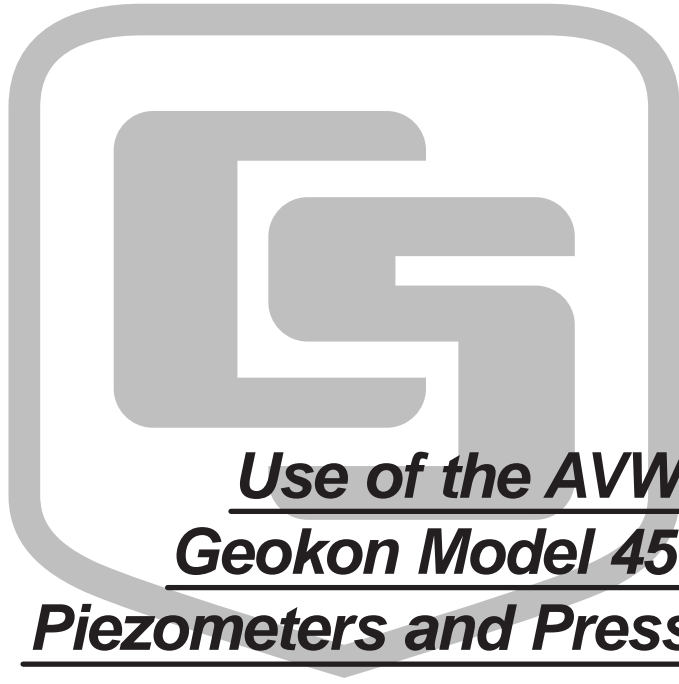


INSTRUCTION MANUAL



**Use of the AVW1 and AVW4 with
Geokon Model 4500 Vibrating Wire
Piezometers and Pressure Transducers**

Revision: 1/92

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USE OF THE AVW1 AND AVW4 WITH GEOKON MODEL 4500 VIBRATING WIRE PIEZOMETERS AND PRESSURE TRANSDUCERS

1. GENERAL INFORMATION

The CR10 is the only CSI datalogger that has the capability of measuring the vibrating wire pressure sensor in addition to the piezoresistive type of strain gage sensor. The CR10 can measure vibrating wire sensors with short leads without the AVW1 or AVW4. However, the AVW1 and AVW4 provide important signal conditioning that 1) completes the thermistor bridge for the measurement of the sensor's temperature, 2) converts the swept frequency excitation from 2.5 volts peak to peak to 12 volts peak to peak, 3) provides transformer isolation and consequent noise reduction for the vibrating wire signal, and 4) provides additional transient protection for both the temperature and vibrating wire circuits.

The AVW1 and AVW4 are designed and tested over the environmental range from -25°C to +50°C. CSI recommends that special temperature testing be done at the factory if the AVW's are to operate at temperatures outside this range.

The vibrating wire pressure sensor has a good reputation for long term stability. The sensor utilizes a change in the frequency of a vibrating wire to sense pressure. Two measurements are usually made on a vibrating wire sensor. The first is the measurement of the temperature of the probe to compensate for changes in its temperature. The second is the measurement of the frequency of the vibrating wire.

This manual covers the use of the CR10 and AVW1 or AVW4 with Geokon's Model 4500 vibrating wire sensor series. Sections 2 and 3 of this manual cover the temperature and vibrating wire measurements respectively. Sections 4 and 5 give detail concerning the use of the AVW1 and AVW4.

Geokon includes a calibration sheet and instruction manual with each sensor or group of sensors they sell. Geokon's manual should be consulted for information on sensor selection and installation. Geokon's address and phone number are: 48 Spencer Street, Lebanon, NH 03766, (603) 448-1562.

1.1 SENSOR SELECTION

The vibrating wire sensors may be purchased as either vented or sealed sensors. The vented sensors have a small hollow "vent tube" that connects the hollow chamber behind the diaphragm to the atmosphere. The vent tube allows the barometric pressure to act on both sides of the diaphragm equally which removes the barometric pressure from the reading. A pressure reading with out a barometric pressure component is referred to as "gage" pressure. A pressure reading with a barometric pressure component is referred to as "absolute" pressure. One disadvantage of the vented sensor is that the cable, which contains the vent tube, is more expensive than the cable for the unvented sensor. For this reason, it may be more economical to buy unvented sensors and use an extra one as a barometer to remove the barometric pressure. A second small disadvantage of the vented sensors is that they require the use of desiccant, which must be changed periodically, to dry the air entering the vent tube.

1.2 SENSOR CARE AND INSTALLATION

The moisture trap of the vented models should be kept closed until readings are to be taken. **DO NOT FORGET** to remove the screw that plugs the moisture trap when readings are to be taken.

The large diameter diaphragm used in the low pressure sensor requires special care when handling. Avoid bumping or jarring the sensor.

Orientation of the 4500 series sensors will affect the zero reading. Readings should be taken with the sensor in the same orientation at all times. When installing the 4500 series sensors, certain steps should be followed to obtain proper zero readings.

The cavity between the sintered filter cap and the diaphragm should be filled with clean water without any air bubbles.

In most cases the sensor is made to output water height or pressure relative to a measured level. In this case the pressure sensor should

AVW1/AVW4

be placed at the desired level and allowed to come to temperature equilibrium with its surroundings (5 minutes or more). The multiplier determined in equation 3.2-2 should be entered and 0.0 should be entered for the offset. After the temperature and the reading has stabilized, determine the value that would have to be added to the reading to obtain the measured level. Enter this value as the offset.

In some cases there is no measured reference. In order to obtain the correct offset under these

conditions, lower the sensor to a point just above the water level and wait 5 minutes. Use the multiplier, an offset of 0.0, and the temperature correction function determined in Sections 3.2 and 3.5 to obtain a reading. Record the reading. Solve equation 3.2-3 for the new offset by plugging in the "reading" in the place of the "[Gage Factor * Zero Reading]" and the "Barometric Pressure" from an accurate barometer or a reference sensor in the place of "Po" unless it is a vented sensor then use 0 in the place of "Po". Enter the new offset.

SECTION 2. TEMPERATURE MEASUREMENT

2.1 GENERAL

The vibrating wire probe includes a thermistor which is used to measure the temperature of the probe. Probe temperature is used to correct errors in the vibrating wire measurement caused by changes in the temperature of the probe. The temperature correction is most important when the temperature of the medium the probe is measuring is changing (e.g. water temperature in a river or shallow lake). When concerned with the absolute reading, it is also important to make the temperature correction if the medium temperature differs from the calibration temperature. In a deep well where the water temperature does not change, the error due to temperature can be removed by allowing the sensor to come to thermal equilibrium and adjusting the sensor reading to read the correct depth by means of an offset.

2.2 ACCURACY AND RESOLUTION

The accuracy of the temperature measurement is a function of the following factors listed in decreasing importance: **1)** the thermistor's interchangeability, **2)** the resistance of the wire, **3)** the linearization error, **4)** the precision of the bridge resistors, **5)** the accuracy of the datalogger's voltage measurement, and **6)** the temperature coefficient of the bridge resistors. The interchangeability of the thermistor is $\pm 0.5^{\circ}\text{C}$ although a thermistor with $\pm 0.2^{\circ}\text{C}$ interchangeability is an option. The error due to wire resistance is normally less than $\pm 0.5^{\circ}\text{C}$ (see Figure 2.2-1 through 2.2-4). The linearization error is $\pm 0.15^{\circ}\text{C}$ (see Figure 2.2-5) over the range from -5 to $+60^{\circ}\text{C}$. The precision

of the bridge resistors ($\pm 0.1\%$) results in a tolerance of $\pm 0.03^{\circ}\text{C}$. The accuracy of the datalogger's voltage measurement ($\pm 0.015\%$) results in a tolerance of $\pm 0.01^{\circ}\text{C}$. The temperature coefficient of the bridge resistors (10 ppm/ $^{\circ}\text{C}$) results in a tolerance of $\pm 0.0003^{\circ}\text{C}/^{\circ}\text{C}$.

Errors four, five, and six mentioned above are all less than $\pm 0.03^{\circ}\text{C}$ each and can probably be ignored. The wire resistance is primarily an offset error and its affect on the pressure measurement is removed by the initial calibration. Errors caused by the change in wire resistance due to temperature, thermistor interchangeability, and the linearization error are not removed by the initial calibration.

Ignoring the offset errors, the remaining temperature accuracy is expected to be about $\pm 0.7^{\circ}\text{C}$. The temperature correction for the vibrating wire measurement is typically less than 0.05 psi/ $^{\circ}\text{C}$. A $\pm 0.7^{\circ}\text{C}$ temperature error would result in a 0.035 psi (± 1.0 inch H₂O) error on a 50 psi Full Scale range.

The thermistor, Dale Electronics part number 1C3001-B3 is the standard with an interchangeability of $\pm 0.5^{\circ}\text{C}$. The optional thermistor, Dale Electronics part number 1C3001-C3 has an inter-changeability of $\pm 0.2^{\circ}\text{C}$. Both of the above thermistors have the same resistance vs. temperature relationship as the YSI thermistor number 44005.

The following table shows the relationship between temperature and resistance, volts, CR10 output, and linearization error.

TABLE 2.2-1. Temperature vs. Thermistor Resistance, V, $^{\circ}\text{C}$, and Linearization Error

TEMP $^{\circ}\text{C}$	SENSOR RESISTANCE, OHMS	VOLTS OUT	CR10 OUTPUT, $^{\circ}\text{C}$	ERROR $^{\circ}\text{C}$
-5	12700	0.668449	-5.09136	-0.09136
-4	12050	0.692520	-4.02248	-0.02248
-3	11440	0.716743	-2.98315	0.016846
-2	10860	0.741399	-1.95557	0.044427
-1	10310	0.766400	-0.93843	0.061560

AVW1/AVW4

<u>TEMP</u> <u>°C</u>	<u>SENSOR</u> <u>RESISTANCE,</u> <u>OHMS</u>	<u>VOLTS</u> <u>OUT</u>	<u>CR10</u> <u>OUTPUT,°C</u>	<u>ERROR</u> <u>°C</u>
0	9796	0.791339	0.057084	0.057084
1	9310	0.816459	1.045822	0.045822
2	8851	0.841694	2.029469	0.029469
3	8417	0.867031	3.011520	0.011520
4	8006	0.892474	3.995450	-0.00454
5	7618	0.917902	4.979594	-0.02040
6	7252	0.943253	5.963992	-0.03600
7	6905	0.968616	6.954119	-0.04588
8	6576	0.993956	7.950259	-0.04974
9	6265	1.019160	8.949209	-0.05079
10	5971	1.044190	9.950388	-0.04961
11	5692	1.069107	10.95688	-0.04311
12	5427	1.093900	11.96879	-0.03120
13	5177	1.118368	12.97814	-0.02185
14	4939	1.142700	13.99297	-0.00702
15	4714	1.166697	15.00510	0.005100
16	4500	1.190476	16.01954	0.019545
17	4297	1.213945	17.03265	0.032652
18	4105	1.237011	18.04042	0.040421
19	3922	1.259826	19.04982	0.049822
20	3748	1.282314	20.05785	0.057855
21	3583	1.304393	21.06127	0.061275
22	3426	1.326119	22.06310	0.063105
23	3277	1.347418	23.06048	0.060484
24	3135	1.368363	24.05747	0.057474
25	3000	1.388888	25.05167	0.051679
26	287	1.408926	26.04042	0.040428
27	2750	1.428571	27.02901	0.029014
28	2633	1.447932	28.02396	0.023968
29	2523	1.466619	29.00577	0.005777
30	2417	1.485089	29.99901	-0.00098
31	2317	1.502945	30.98300	-0.01699
32	2221	1.520496	31.97513	-0.02486
33	2130	1.537515	32.96311	-0.03688
34	2042	1.554339	33.96711	-0.03288
35	1959	1.570549	34.96239	-0.03760
36	1880	1.586294	35.95767	-0.04232
37	1805	1.601537	36.95011	-0.04988
38	1733	1.616448	37.95060	-0.04939
39	1664	1.631002	38.95742	-0.04257
40	1598	1.645169	39.96844	-0.03155
41	1535	1.658925	40.98115	-0.01884
42	1475	1.672240	41.99263	-0.00736
43	1418	1.685090	42.99951	-0.00048
44	1363	1.697677	44.01695	0.016954
45	1310	1.709986	45.04335	0.043350
46	1260	1.721763	46.05610	0.056109
47	1212	1.733222	47.07191	0.071918
48	1167	1.744104	48.06568	0.065681

TEMP °C	SENSOR RESISTANCE, OHMS	VOLTS OUT	CR10 OUTPUT, °C	ERROR °C
49	1123	1.754878	49.07873	0.078734
50	1081	1.765287	50.08636	0.086361
51	1040	1.775568	51.11067	0.110677
52	1002	1.785204	52.09809	0.098095
53	965	1.794687	53.09674	0.096746
54	929.6	1.803855	54.08849	0.088499
55	895.8	1.812697	55.07032	0.070322
56	863.3	1.821281	56.04819	0.048193
57	832.2	1.829571	57.01651	0.016519
58	802.3	1.837613	57.97896	-0.02103
59	773.7	1.845372	58.92977	-0.07022
60	746.3	1.852867	59.86962	-0.13037

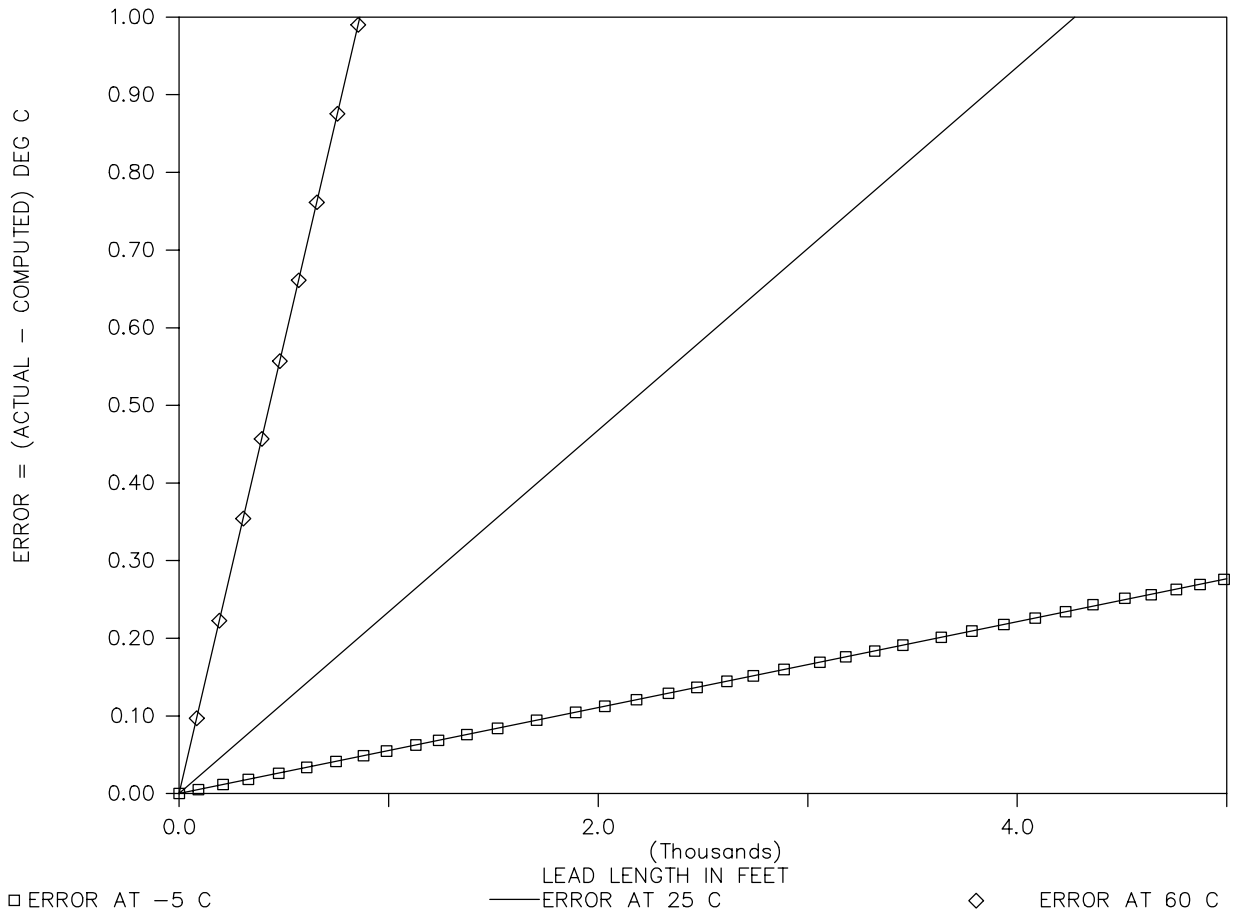


FIGURE 2.2-1. Temperature Measurement Error at Three Temperatures as a Function of Lead Length. Wire is 22 AWG with 16 ohms per 1000 feet.

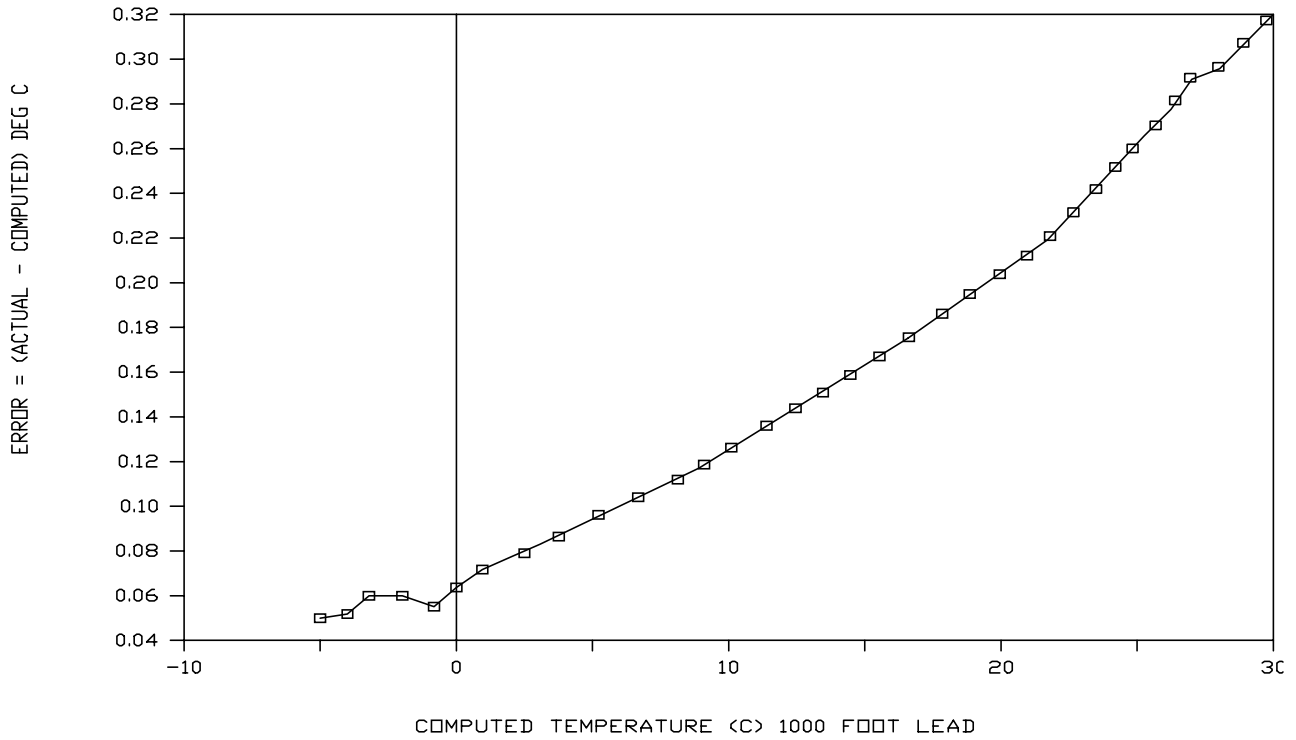


FIGURE 2.2-2. Temperature Measurement Error on a 1000 foot Lead. Wire is 22 AWG with 16 ohms per 1000 feet.

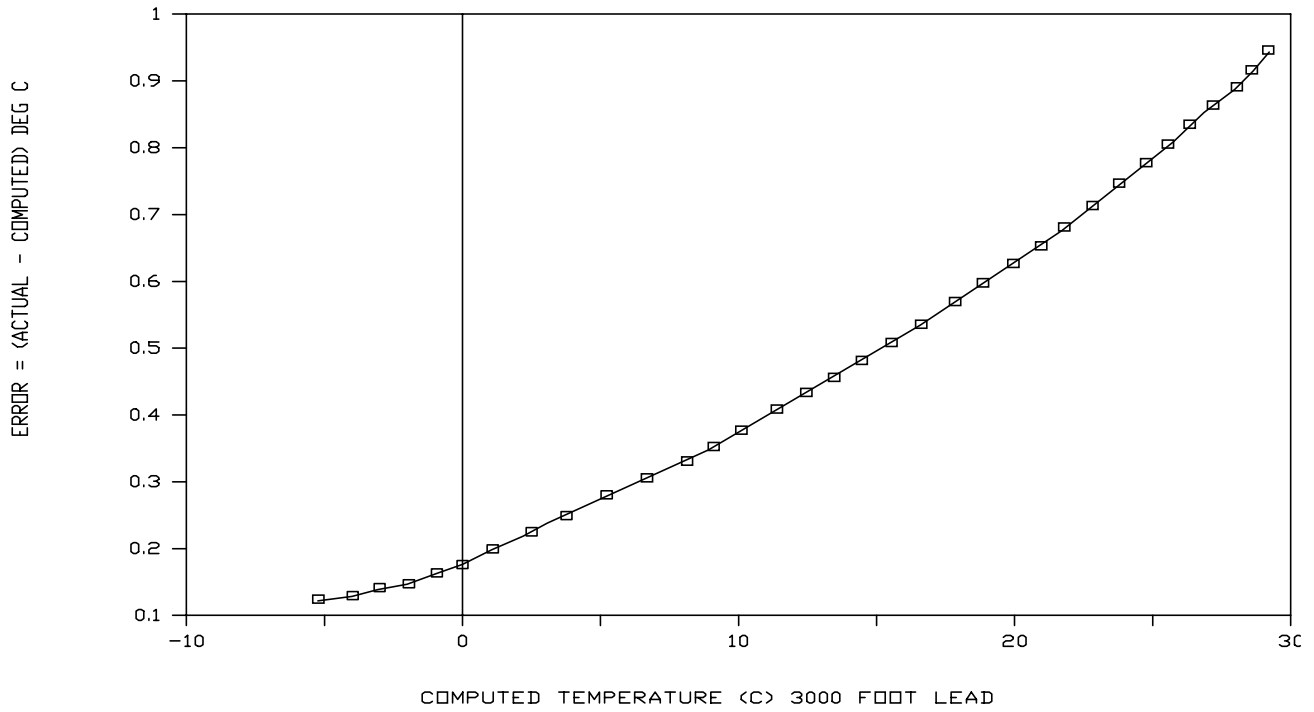


FIGURE 2.2-3. Temperature Measurement Error on a 3000 foot Lead. Wire is 22 AWG with 16 ohms per 1000 feet.

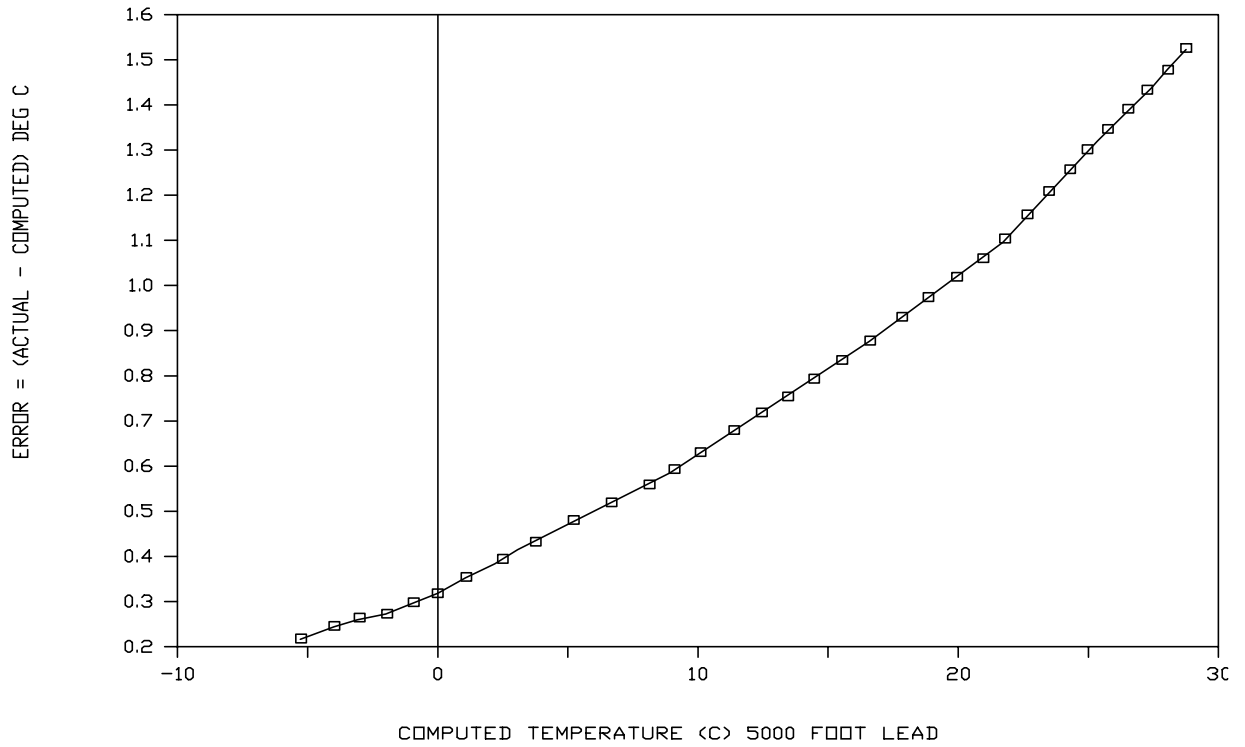


FIGURE 2.2-4. Temperature Measurement Error on a 5000 foot Lead. Wire is 22 AWG with 16 ohms per 1000 feet.

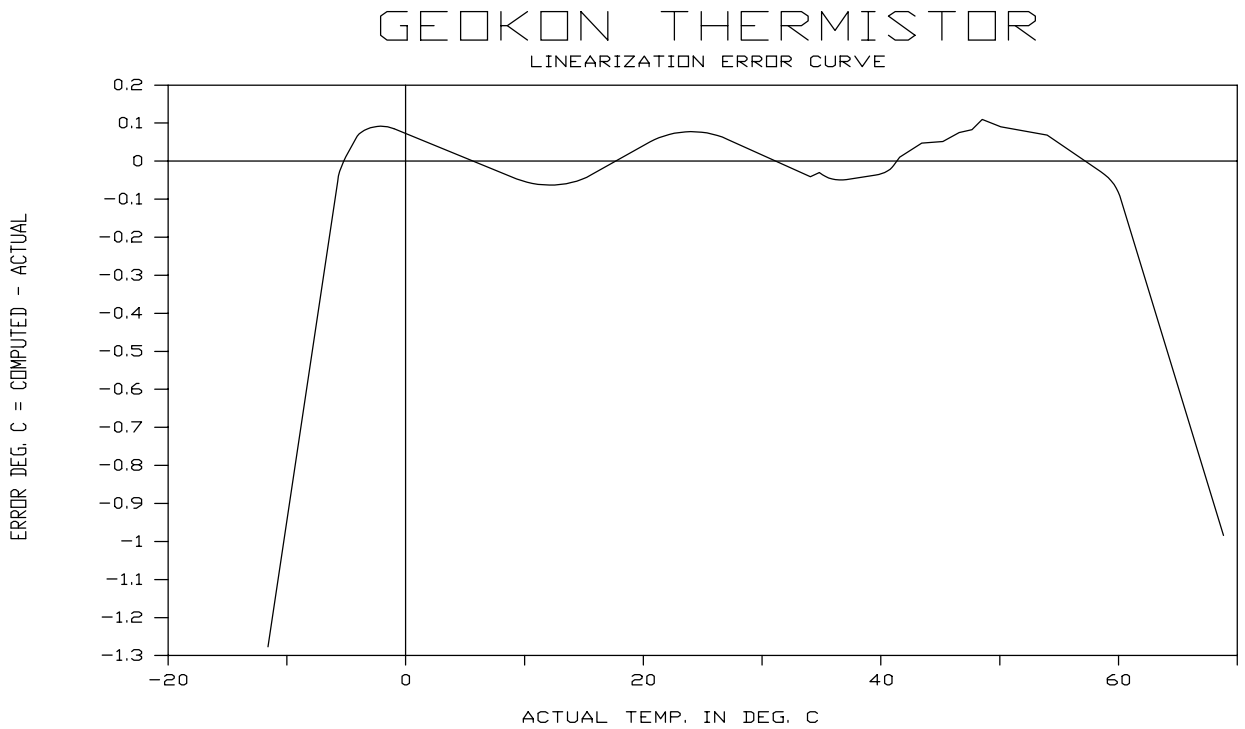


FIGURE 2.2-5. Thermistor Linearization Error

2.3 PROGRAMMING AND SENSOR HOOK-UP

Measure the thermistor with Instruction 4 using a measurement range of 2500 mV fast, an excitation voltage of 2500 mV, a delay of 1, and a multiplier of 0.001. The resulting value is linearized with Instruction 55 using the following coefficients: C0 = -104.78, C1 = 378.11, C2 = -611.59, C3 = 544.27, C4 = -240.91, C5 = 43.089. The output is in degrees Celsius and covers the range from -5°C to +60°C. Due to the small current requirement, up to 118 thermistors could theoretically be powered by one excitation channel.

When measuring the Geokon temperature through CSI's AVW1 or AVW4, see Sections 4 or 5 respectively for hook up information.

NOTE: This manual covers AVW1's with serial number 1093 and up plus serial numbers 1002, 1034, 1040A, 1041, 1042, 1051, 1052, 1055, 1057, 1058, 1059, 1069, 1071, 1073, 1076, 1080, 1084, 1086, 1087, 1088, 1088A, 1089A, 1090A, 1091A, and 1092A. This manual also covers AVW4s with serial number 1045 and up plus serial numbers 1034 and 1038. These serial numbers mark a change in circuitry that changes the excitation voltage for the temperature measurement from -2500 mV (before) to +2500 mV (after). The multiplier also changed from -.001 (before) to +.001 (after). The values of the resistors in locations B4 and C4 for the AVW1 and locations D4 and E4 for the AVW4 were changed to the values shown in the current schematics.

When measuring the Geokon temperature directly with the CR10, connect the leads and bridge completion resistors as shown in Figure 2.3-1.

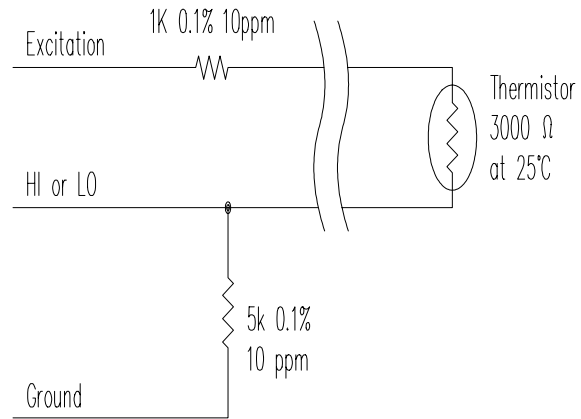


FIGURE 2.3-1. Direct Measurement of the Geokon Thermistor

SECTION 3. VIBRATING WIRE MEASUREMENT

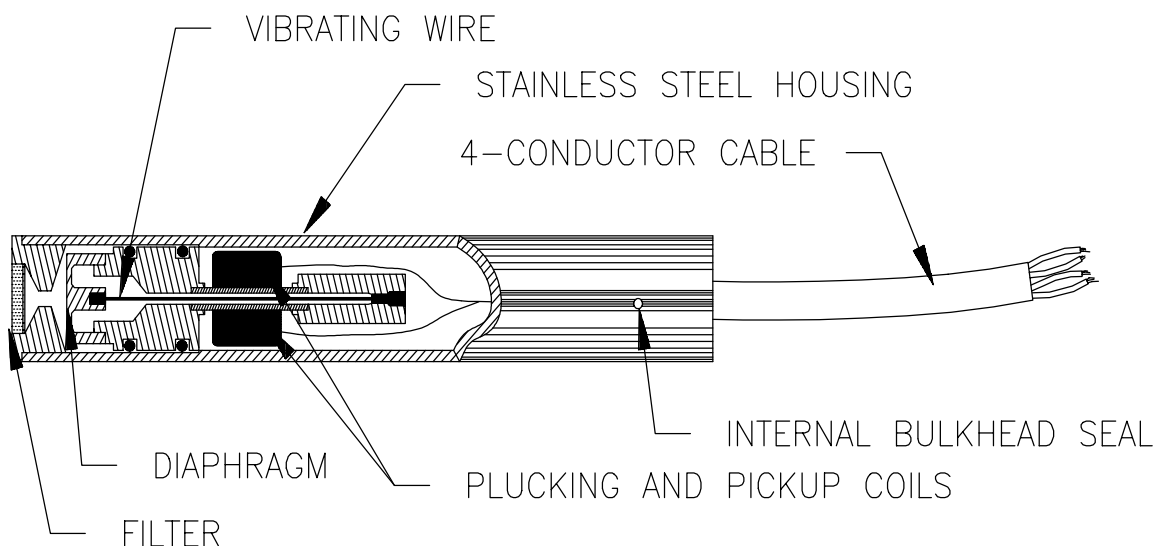


FIGURE 3.1-1. A Vibrating Wire Sensor

3.1 GENERAL

Figure 3.1-1 illustrates how an increase in pressure on the diaphragm decreases the tension on the wire attached to the diaphragm. A decrease in the wire tension decreases the resonant frequency in the same way that loosening a string on a guitar decreases its frequency. Therefore, the resonant frequency of the vibrating wire sensor decreases with increasing pressure.

The Vibrating Wire Measurement Instruction excites the "plucking" and "pickup" coils shown in the above figure with a "swept" frequency. A "swept" frequency is a group of different frequencies that are sent one right after another starting with the lowest frequency and ending with the highest. The lowest and highest frequencies are entered by the user in units of hundreds of Hz. The CR10 requires 150 ms to "sweep" through all of the frequencies. This "swept" frequency causes the wire to vibrate at each of the individual frequencies. Ideally, all of the frequencies except the one matching the resonant frequency of the wire will die out in a very short time. The wire will vibrate with the resonant frequency for a relatively long period of time and as it does so it will cut the lines of flux

in the "plucking" and "pickup" coils inducing the same frequency on the lines to the CR10. After waiting for the non resonant frequencies to die out (20 ms) the CR10 accurately measures how much time it takes to receive a user specified number of cycles. Knowing the length of time and the number of cycles, the CR10 then computes the square of the frequency expressed in units of $\text{kHz}^2 (= 1/T^2$ where T is the period in milliseconds).

3.2 MULTIPLIER & OFFSET

The 50 psi vibrating wire pressure sensor used in this example is the Geokon Model 4500SV-50. It is vented to the atmosphere so it will not be affected by changes in barometric pressure. Each sensor is individually calibrated and has a unique set of calibration coefficients. A calibration sheet contains the Model Number, Serial Number, Gage Factor (psi/digit), Temperature Coefficient (psi/°C), Zero Reading (digits), zero Period (microseconds), calibration Temperature (°C) and calibration Barometric Pressure (inches Hg). A Geokon "digit" is defined as the square of the frequency in kHz multiplied by 1000 (1 digit = $0.001 \text{ kHz}^2 = 1000 \text{ Hz}^2$). The calibration coefficients for the sensor with serial number 3998 are given below:

TABLE 3.2-1. Calibration Data for Sensor 3998

Gage Factor	Temp. Coeff.	Zero Rdg.	Period	Temp.	Baro.
<u>(psi/digit)</u>	<u>(psi/oC)</u>	<u>(digit)</u>	<u>(usecond)</u>	<u>(oC)</u>	<u>(in Hg)</u>
0.0151	-0.0698	9431	325.6	24	29.51

The equation to change the CR10's output into pressure (psi) exerted on the sensor is given below:

$$P = [M * X] + B \quad 3.2-1$$

where P is the pressure in psi and X is the result of measurement Instruction 28 in kHz² (= 1/T² where T is the period in milliseconds). The multiplier (M) and offset (B) are determined by equations 3.2-2 and 3.2-3.

$$M = -1000(\text{digits/kHz}^2) * \text{Gage Factor} \quad 3.2-2$$

where M is the multiplier in psi/(kHz²) and the Gage Factor is found on the Calibration Sheet in psi/digit.

$$B = P_o + [\text{Gage Factor} * \text{Zero Reading}] \quad 3.2-3$$

where B is the offset in psi and P_o is the pressure in psi at the time of calibration. For vibrating wire sensors not vented to the atmosphere, P_o is the barometric pressure ["Baro."(in Hg) * 0.49116 (psi/in Hg)] at the time of calibration. For the vented sensors, P_o is 0 psi. The Gage Factor (psi/digit) and Zero Reading (digits) are found on the Calibration Sheet.

Example: Using sensor number 3998, the multiplier, offset, and equation for pressure would be:

$$M = (-1000 \text{ digits/kHz}^2) * 0.0151 \text{ psi/digit}$$

$$M = -15.1 \text{ psi/(kHz}^2)$$

$$B = 0.0 \text{ psi} + (0.0151 \text{ psi/digit} * 9431 \text{ digits})$$

$$B = 142.4 \text{ psi}$$

$$P = [-15.1 \text{ psi/(kHz}^2) * X \text{ (kHz}^2)] + 142.4 \text{ psi}$$

3.3 SWEPT FREQUENCY, START AND END

The AVW1 and AVW4 were not designed for use below 1000 Hz.

In general, the starting frequency of the swept frequency for this sensor should be just a bit lower than the frequency at the Full Scale pressure of the sensor. A rough rule of thumb would put the starting frequency at two thirds that of the ending frequency. Almost always the starting frequency should not be lower than half of the ending frequency.

Start Freq. ≤ ([Full Scale Pressure - (Gage Factor * Zero

Reading)]/M)0.5 * 1000 Hz/kHz 3.3-1

Start Freq. ≤ ([50psi - (0.0151psi/digit * 9431digits)]/

[-15.1psi/kHz²])^{0.5} * 1000 Hz/kHz

Start Freq. ≤ 2474 Hz or 24 hundred Hz

In general, the ending frequency of the swept frequency for this sensor should be just a bit higher than the frequency at Zero Pressure.

End Freq. ≥ ([Zero Pressure - (Gage Factor * Zero Reading)]/M)^{0.5}

* 1000 Hz/kHz 3.3-2

End Freq. ≥ ([0.0psi - (0.0151psi/digit * 9431digits)]/

[-15.1psi/kHz²])^{0.5} * 1000 Hz/kHz

End Freq. ≥ 3071 Hz or 31 hundred Hz

Some additional information concerning the swept frequency may be found in Appendix C.

$$SD = \frac{(2 \cdot 15.1 \text{ psi} / (\text{kHz}^2) \cdot 0.00015 \text{ ms})}{(500 \cdot (325.6 \mu\text{s} / 1000 \mu\text{s} / \text{ms}))^3}$$

NOTE: Please remember that sealed (or absolute) sensors calibrated near sea level will read negative at higher elevations due to the decrease in barometric pressure with increasing elevation. In most cases the solution is to load the sensor with extra external pressure to cause it to operate in its calibrated range. For example, a sealed 0 to 5 psi sensor used at 10,000 feet elevation would have to be placed under 10.6 feet of water (4.6 psi) in order to read 0 psi. This is because the barometric pressure at 10,000 feet is about 4.6 psi lower than at sea level.

SD = 0.00026246 psi

RESOLUTION = ±0.00078738 psi

Resolution improves as the number of cycles measured increases but it worsens as the signal level decreases and as the noise increases. The optimum resolution is obtained when the number of cycles measured covers one time constant (τ) of the decay of the signal.

Number of cycles = (τ/T)

where T is the period of the signal in milliseconds and τ is the time in milliseconds required for the signal to decay from its initial peak to peak value to (0.368 * initial peak to peak value). An oscilloscope is required to measure the time constant. The time constants of the Geokon sensors we have measured are typically between one third second and one second.

The amount of time required to make one repetition of the vibrating wire measurement is given below:

150. ms to sweep the frequency

20. ms delay

(1.5cycles + #cycles measured) * period of the signal in ms

3.4 RESOLUTION VS. "# OF CYCLES"

CSI and Geokon recommend that the number of cycles measured be between 200 and 500. Five hundred cycles would probably be the optimum for most applications. The measurement of more than 500 cycles is not recommended without testing. Some sensors, for example, will not vibrate a full 1000 cycles at all pressures in their pressure range.

For the sake of this discussion we will define the resolution of the vibrating wire measurement as plus or minus three standard deviations (±3 SD) of the vibrating wire measurement. The standard deviation of the measurement in psi is given by the following equation:

$$SD = (2 \cdot M \cdot C) / (N \cdot T^3) \tag{3.4-1}$$

where M is the multiplier computed in 3.2-2. "C" is 0.00015 ms which is the typical standard deviation of a time interval measurement on the CR10 using a 4 mV peak to peak signal with no external noise. "N" is the number of cycles timed to determine the period (T) in ms of the signal being measured.

The standard deviation is greater when the period is shorter. The period is shortest at zero pressure so the "Period" at zero pressure given in Table 3.2-1 is used for the example below:

3.5 TEMPERATURE CORRECTION

The equation used to remove errors caused by changes in the sensor's temperature is found below:

$$P_t = P + (\text{TEMP. COEFF.}) \cdot (T - T_o) \tag{3.5-1}$$

where P_t(psi) is the temperature corrected pressure. P(psi) is the uncorrected pressure from equation 1. T(°C) is the current temperature of the sensor. T_o(°C) is the "Temp." on the Calibration Sheet which is the temperature of the sensor at the time of calibration. TEMP. COEFF.(psi/°C) is also found on the Calibration Sheet. It is important to note that the "TEMP. COEFF." can be either positive or negative.

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Example: Using sensor number 3998 and assuming a sensor temperature of 15°C, the corrected pressure would be:

$$P_t = P_{psi} + (-0.0698 \text{ psi/}^\circ\text{C}) * (15^\circ\text{C} - 24^\circ\text{C})$$

$$= P_{psi} + 0.6282 \text{ psi}$$

3.6 DELAY BETWEEN MEASUREMENTS

The vibrating wire sensor should not be excited more often than once every five time constants if high resolution is important. If more than one repetition is specified the "delay before excitation applied" parameter can be used to ensure the proper amount of delay between excitations. Excitation of the sensor while the wire is still vibrating can cause the signals to add or subtract (in phase or out of phase) causing the wire to vibrate excessively hard or almost not at all.

If two back to back measurements are required they can be done one of two ways. With the AVW4 the repetitions parameter must be set to 2--. The "--" instructs the CR10 to excite both sensors, delay 20 ms, measure the first sensor, and then measure the second sensor. There is no delay or re-application of the excitation between the measurements. Back to back measurements require that the sum of the number of cycles measured on each sensor not exceed the time constant of the last sensor or the signal may have become too weak to be measured. (e.g., two sensors measured separately, each having a time constant equal to 700 cycles would have to be measured back to back with a maximum of 350 cycles.) Back to back measurements with two AVW1s and two excitation channels can be done simply by entering Instruction 28 twice, once for the first sensor and once for the second. In this case the second AVW1 measurement will begin 170 milliseconds after the first one ended.

SECTION 4. THE AVW1

4.1 GENERAL

The AVW1 contains circuitry needed to interface Geokon's 4500 series vibrating wire sensor to the CR10. The AVW1 is designed to interface one vibrating wire sensor (temperature and pressure) to two single ended CR10 channels. The AVW1 has no quiescent current drain. The current drain during the very short (2.4 ms) temperature measurement is .4 mA or lower. The current drain during the vibrating wire measurement (170 ms to 500 ms) is 32 mA. The AVW1 is 2.5 inches long by 2.5 inches wide by 1.4 inches high. The silk screening for the AVW1 is shown below.

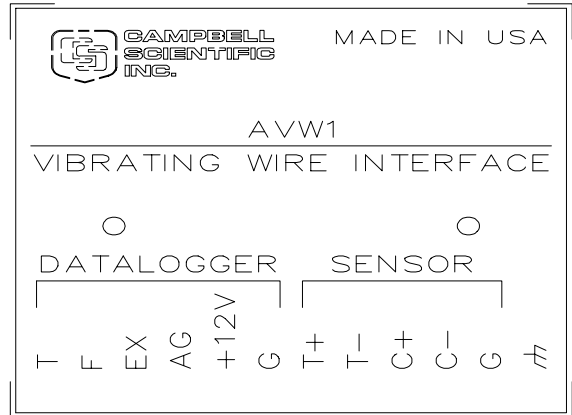


FIGURE 4.1-1. The AVW1

4.2 SENSOR HOOK UP

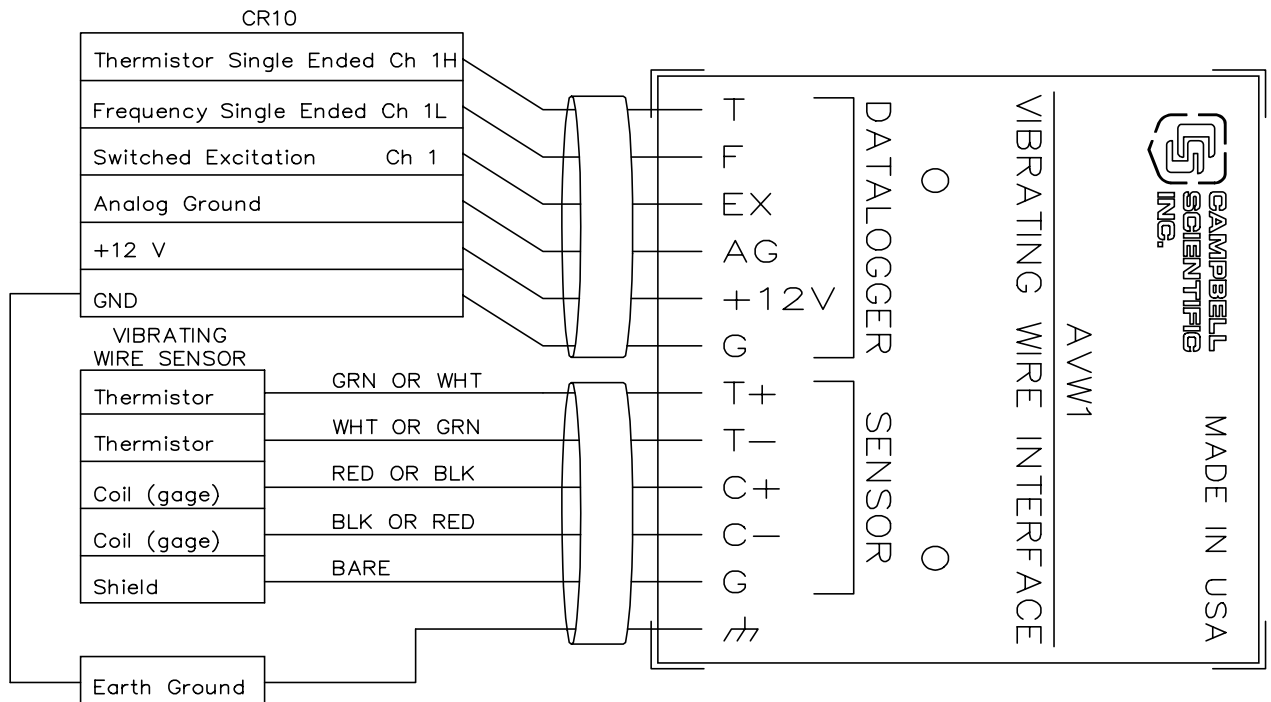


FIGURE 4.2-1. Hook up to AVW1

4.3 WELL MONITORING EXAMPLE

In this example the vibrating wire sensor is used to monitor the Distance from the lip of the well to the water surface in a 150 foot well. The water level is expected to stay within 40 to 80 feet of the lip so the 50 psi pressure sensor is placed approximately 100 feet below the lip of

the well. The same sensor used in Section 3.2 for the computation of the multiplier etc. (serial number 3998) will be used again in this example.

In the example program that follows the depth of water above the vibrating wire sensor is measured in psi and then converted into feet of

AVW1/AVW4

water. The water depth above the sensor is referred to as the "Reading" in the following equation. The Reading decreases with increasing "Distance" from lip of well to water surface so the Distance is computed by subtracting the Reading from the Offset as shown in the above figure and the following equation.

$$\text{Distance} = \text{Offset} - \text{Reading}$$

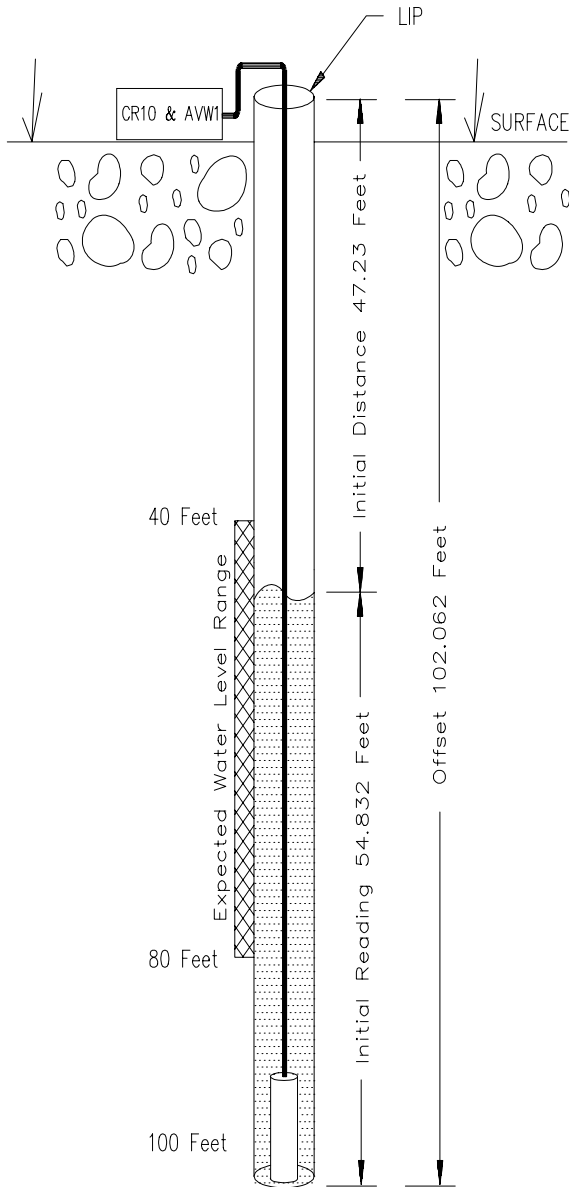


FIGURE 4.3-1. Well Monitoring Example

The "Initial Distance" to the water surface is measured with a chalked line to be 47.23 feet below the lip. The "Initial Reading" is 54.832

feet (of head above the sensor). Solving the above equation for the Offset, one obtains:

$$\text{Offset} = \text{Initial Distance} + \text{Initial Reading}$$

$$= 47.23 \text{ feet} + 54.832 \text{ feet}$$

$$= 102.062 \text{ feet}$$

The following is a sample program that measures the temperature and frequency of the vibrating wire sensor and stores the temperature ($^{\circ}\text{C}$), pressure (psi), temperature corrected pressure (psi), correction factor (psi), temperature corrected pressure (feet of H_2O), and Distance from the lip to the water surface (feet) in Input Locations 1-6 respectively. This example assumes the sensor has been connected as shown in Figure 4.2-1.

Program: AVW & CR10 USED TO MEASURE 1 GEOKON VIBRATING WIRE SENSOR.

```

*          1          Table 1 Programs
01:       10          Sec. Execution Interval

01:       P4          Excite,Delay,Volt(SE)
01:       1          Rep
02:       15          2500 mV fast Range
03:       1          IN Chan
04:       1          Excite all reps w/EXchan 1
05:       1          Delay (units .01sec)
06:       2500        mV Excitation
07:       1          Loc [:TEMP C]
08:       .001        Mult
09:       0.0000      Offset

02:       P55        Polynomial
01:       1          Rep
02:       1          X Loc TEMP C
03:       1          F(X) Loc [:TEMP C]
04:       -104.78     C0
05:       378.11      C1
06:       -611.59     C2
07:       544.27      C3
08:       -240.91     C4
09:       43.089      C5
    
```

03:	P28	Vibrating Wire (SE)	07:	P37	Z=X*F Converts psi to negative ft H20
01:	1	Rep	01:	3	X Loc Pt psi
02:	2	IN Chan	02:	-2.3067	F
03:	1	Excite all reps w/EXchan 1	03:	5	Z Loc [:-Pt FEET H20]
04:	24	Starting Freq. (units=100 Hz)	08:	P34	Z=X+F Adds the Offset to the negative of the Reading to obtain the Distance from lip of the well to water surface.
05:	31	End Freq. (units=100 Hz)	01:	5	X Loc -Pt FEET H20
06:	500	No. of Cycles	02:	102.06	F OFFSET
07:	0000	Rep delay (units=.01sec)	03:	6	Z Loc [:DISTANCE FEET]
08:	2	Loc [:PRESS psi]	09:	P	End Table 1
09:	-15.1	Mult			
10:	142.4	Offset			
04:	P34	Z=X+F			
01:	1	X Loc TEMP C			
02:	-24	F calibration "Temp." in C			
03:	4	Z Loc [:(T-To)*C]			
05:	P37	Z=X*F			
01:	4	X Loc (T-To)*C			
02:	-.0698	F "Temp. Coeff."			
03:	4	Z Loc [:(T-To)*C]			
06:	P33	Z=X+Y			
01:	2	X Loc PRESS psi			
02:	4	Y Loc (T-To)*C]			
03:	3	Z Loc [:-Pt psi]			

First 99 Input Location Labels:

- 1:TEMP C
- 2:PRESS psi
- 3:Pt psi
- 4:(T-To)*C
- 5:Pt Ft H20
- 6:DISTAN FT

AVW1/AVW4

SECTION 5. THE AVW4

5.1 GENERAL

The AVW4 contains circuitry needed to interface Geokon's 4500 series vibrating wire sensor to the CR10. The AVW4 is designed to interface four vibrating wire sensors (temperature and pressure) to eight single ended CR10 channels. The AVW4 has no

quiescent current drain. The current drain during the very short (2.4 ms) temperature measurement is .4 mA per channel or lower. The current drain during each vibrating wire measurement (170 ms to 500 ms) is 32 mA. The AVW4 is 6.7 inches long by 2.9 inches wide by 1.4 inches high.

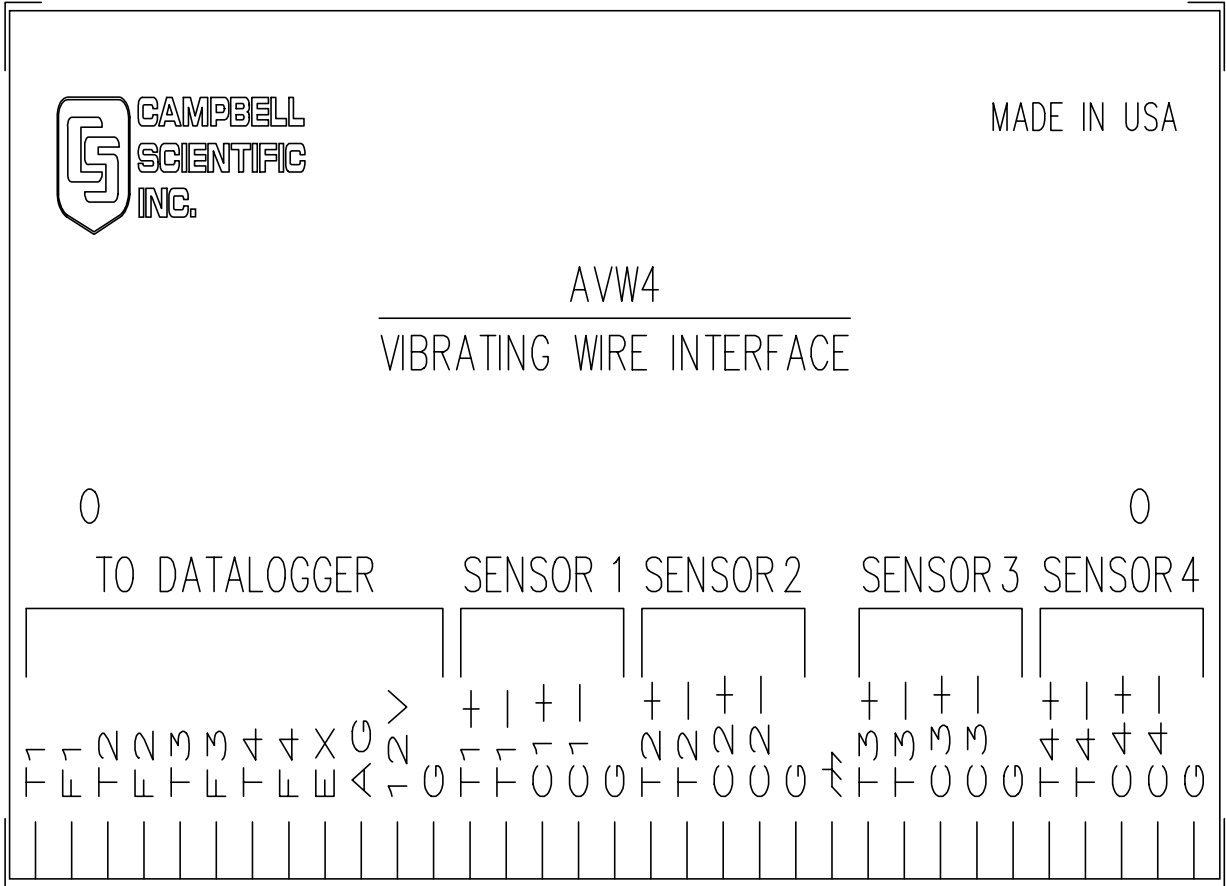


FIGURE 5.1-1. The AVW4

5.2 SENSOR HOOK UP

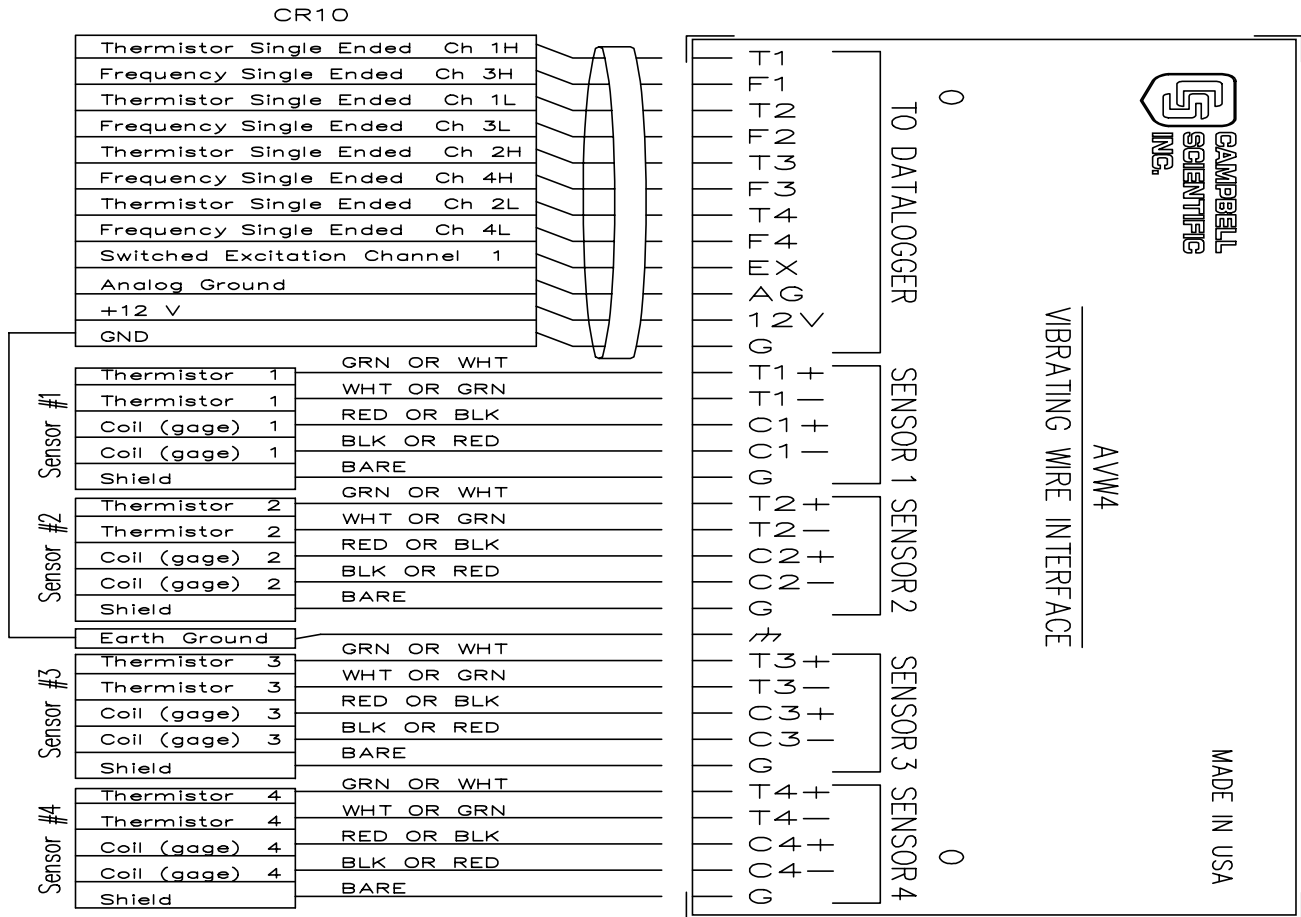


FIGURE 5.2-1. Hook up for AVW4

5.3 DATALOGGER PROGRAMMING

The following is a sample program that measures four sealed Geokon sensors and stores the temperature, pressure, pressure corrected for temperature, and barometric corrected pressure in psi in Input Locations 1..4, 5..8, 9..12, and 10..12 respectively. The example utilizes the calibration data given previously from sensor number 3998. The first sensor measures barometric pressure only and is used to remove atmospheric pressure changes from the readings on the other three sensors. This example assumes the sensors have been connected as shown in the sensor hookup diagram.

Program: AVW4 & CR10 USED TO MEASURE 4 GEOKON SENSORS. THE FIRST SENSOR SERVES AS A BAROMETER AND IS SUBTRACTED FROM THE OTHER THREE TO MEASURE THREE WATER PRESSURES IN PSI EVERY FIVE MINUTES.

*	1	Table 1 Programs
01:	300	Sec. Execution Interval
01:	P4	Excite,Delay,Volt(SE)
01:	4	Reps
02:	15	2500 mV fast Range
03:	1	IN Chan
04:	1	Excite all reps w/EXchan 1
05:	1	Delay (units .01sec)
06:	2500	mV Excitation
07:	1	Loc [:TEMP C #1]
08:	.001	Mult
09:	0.0000	Offset

02:	P55	Polynomial	07:	P34	Z=X+F ASSUMES CALIBRATION TEMP. = 24°C
01:	4	Reps	01:	1--	X Loc TEMP C #1
02:	1	X Loc TEMP C #1	02:	-24	F
03:	1	F(X) Loc [:TEMP C #1]	03:	17--	Z Loc [:T-To°C #1]
04:	-104.78	C0	08:	P36	Z=X*Y
05:	378.11	C1	01:	13--	X Loc Cpsi/C #1
06:	-611.59	C2	02:	17--	Y Loc T-To°C #1
07:	544.27	C3	03:	17--	Z Loc [:T-To°C #1]
08:	-240.91	C4	09:	P33	Z=X+Y
09:	43.089	C5	01:	5--	X Loc psi #1
03:	P28	Vibrating Wire (SE)	02:	17--	Y Loc T-To°C #1
01:	4	Reps	03:	9--	Z Loc [:Pt psi #1]
02:	5	IN Chan	10:	P95	End
03:	1	Excite all reps w/EXchan 1	FOLLOWING THREE INSTRUCTIONS SUBTRACT THE BAROMETRIC PRESSURE FROM THE THREE WATER PRESSURES		
04:	24	Starting Freq. (units=100 Hz)	11:	P35	Z=X-Y
05:	31	End Freq. (units=100 Hz)	01:	10	X Loc Ptb psi #2
06:	500	No. of Cycles	02:	9	Y Loc Pt psi #1
07:	500	Rep delay (units=.01sec) 5 SEC DELAY BETWEEN MEASUREMENTS	03:	10	Z Loc [:Ptb psi #2]
08:	5	Loc [:P psi #1]	12:	P35	Z=X-Y
09:	1	Mult	01:	11	X Loc Ptb psi #3
10:	0	Offset	02:	9	Y Loc Pt psi #1
04:	P53	Scaling Array (A*loc +B) APPLY MULT & OFFSET	03:	11	Z Loc [:Ptb psi #3]
01:	5	Start Loc [:P psi #1]	13:	P35	Z=X-Y
02:	-15.1	A1	01:	12	X Loc Ptb psi #4
03:	142.4	B1	02:	9	Y Loc Pt psi #1
04:	-15.1	A2	03:	12	Z Loc [:Ptb psi #4]
05:	142.4	B2	First 99 Input Location Labels:		
06:	-15.1	A3	1:TEMP C #1	11:Ptbpsi #3	
07:	142.4	B3	2:TEMP C #2	12:Ptbpsi #4	
08:	-15.1	A4	3:TEMP C #3	13:Cpsi/C #1	
09:	142.4	B4	4:TEMP C #4	14:Cpsi/C #2	
05:	P53	Scaling Array (A*loc +B) LOADS TEMP. COEFF.	5:P psi #1	15:Cpsi/C #3	
01:	13	Start Loc [:Cpsi/C #1]	6:P psi #2	16:Cpsi/C #4	
02:	0	A1	7:P psi #3	17:T-To°C #1	
03:	-.0698	B1	8:P psi #4	18:T-To°C #2	
04:	0	A2	9:Pt psi #1	19:T-To°C #3	
05:	-.0698	B2	10:Ptbpsi #2	20:T-To°C #42	
06:	0	A3			
07:	-.0698	B3			
08:	0	A4			
09:	-.0698	B4			
06:	P87	Beginning of Loop TEMPERATURE CORRECTION			
01:	00	Delay			
02:	4	Loop Count			

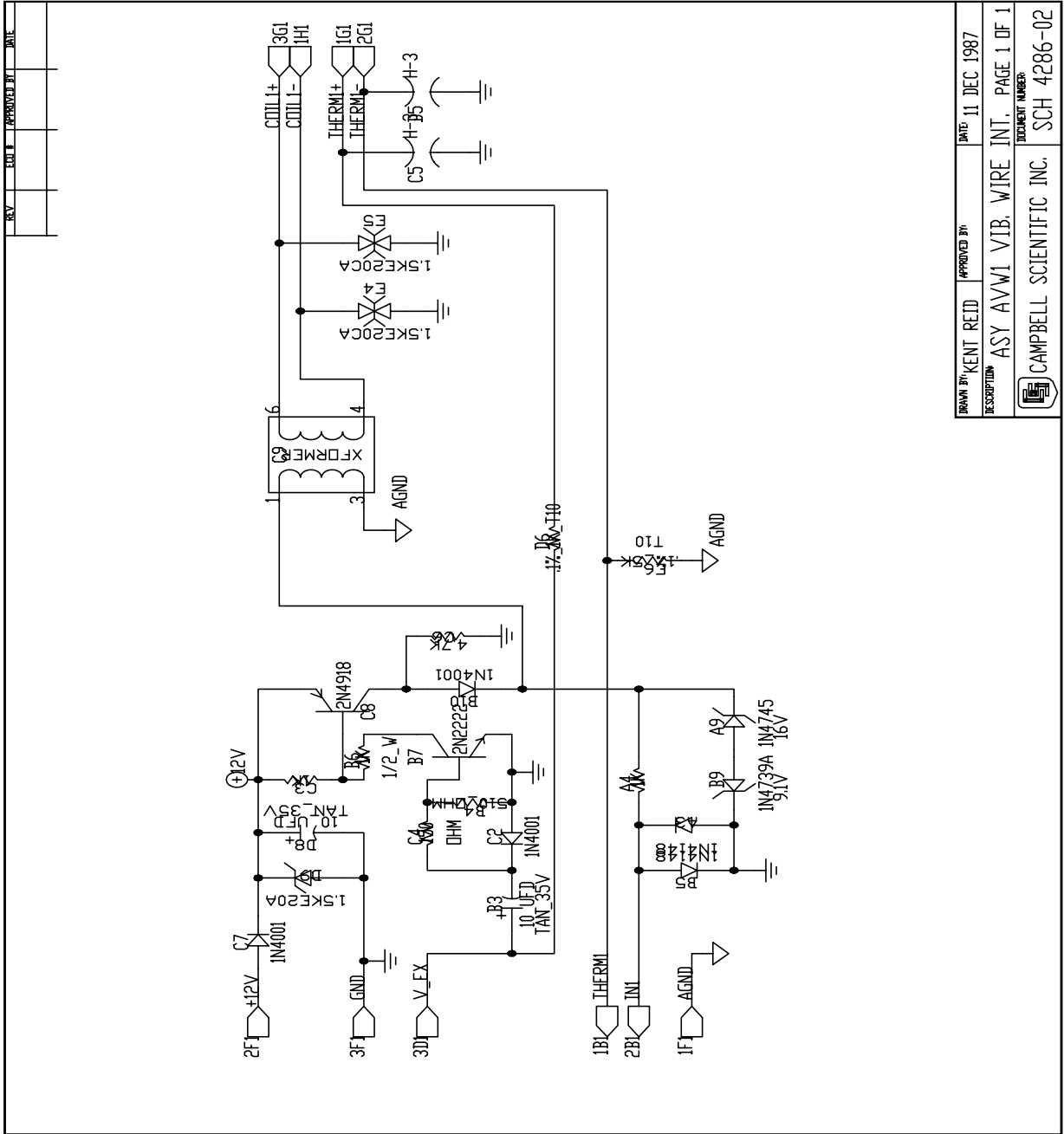
AVW1/AVW4

APPENDIX A. PRESSURE CONVERSION CHART

Multiplication Factors

FROM TO	PSI (lb/in ²)	BAR	MILLIBAR	IN. HG. (at 0°C)	IN. H ₂ O (at 4°C)	MM. HG. (at 0°C)	MM. H ₂ O (at 4°C)	PASCAL (N/m ²)	ATM	TORR
PSI (lb/in ²)	1	14.5039	1.4504 x 10 ⁻²	.491159	3.6127 x 10 ⁻²	1.93368 x 10 ⁻²	1.4223 x 10 ⁻³	1.45038 x 10 ⁻⁴	14.6960	1.9337 x 10 ⁻²
BAR	6.8947 x 10 ⁻²	1	1 x 10 ⁻³	3.3865 x 10 ⁻²	2.4908 x 10 ⁻³	1.3332 x 10 ⁻³	9.8068 x 10 ⁻⁵	1 x 10 ⁻⁵	1.0132	1.3332 x 10 ⁻³
MILLIBAR	68.947	1 x 10 ³	1	33.865	2.4908	1.3332	9.8068 x 10 ⁻²	1 x 10 ⁻²	1.0132 x 10 ³	1.3332
IN. HG. (at 0°C)	2.0360	29.529	2.9529 x 10 ⁻²	1	7.3552 x 10 ⁻²	3.9368 x 10 ⁻²	2.8959 x 10 ⁻³	2.9529 x 10 ⁻⁴	29.920	3.9368 x 10 ⁻²
IN. H ₂ O (at 4°C)	27.680	401.47	.40147	13.596	1	.53525	3.9372 x 10 ⁻²	4.0147 x 10 ⁻³	406.78	.53525
MM. HG. (at 0°C)	51.7149	750.06	.75006	25.401	1.8683	1	7.3558 x 10 ⁻²	7.5006 x 10 ⁻³	760.00	1
MM. H ₂ O (at 4°C)	703.08	1.0197 x 10 ⁴	10.197	345.32	25.399	13.595	1	.10197	1.0332 x 10 ⁴	13.595
PASCAL (N/m ²)	6894.76	1 x 10 ⁵	100	3.3865 x 10 ³	249.08	133.32	9.8068	1	1.0332 x 10 ⁵	133.32
ATM	6.8046 x 10 ⁻²	.98692	9.8692 x 10 ⁻⁴	3.3422 x 10 ⁻²	2.4583 x 10 ⁻³	1.3158 x 10 ⁻³	9.6788 x 10 ⁻⁵	9.8692 x 10 ⁻⁶	1	1.3158 x 10 ⁻³
TORR	51.7149	750.06	.75006	25.401	1.8683	1	7.3558 x 10 ⁻²	7.5006 x 10 ⁻³	760.00	1

APPENDIX B. SCHEMATICS AND STUFFING CHARTS FOR AVW1 AND AVW4

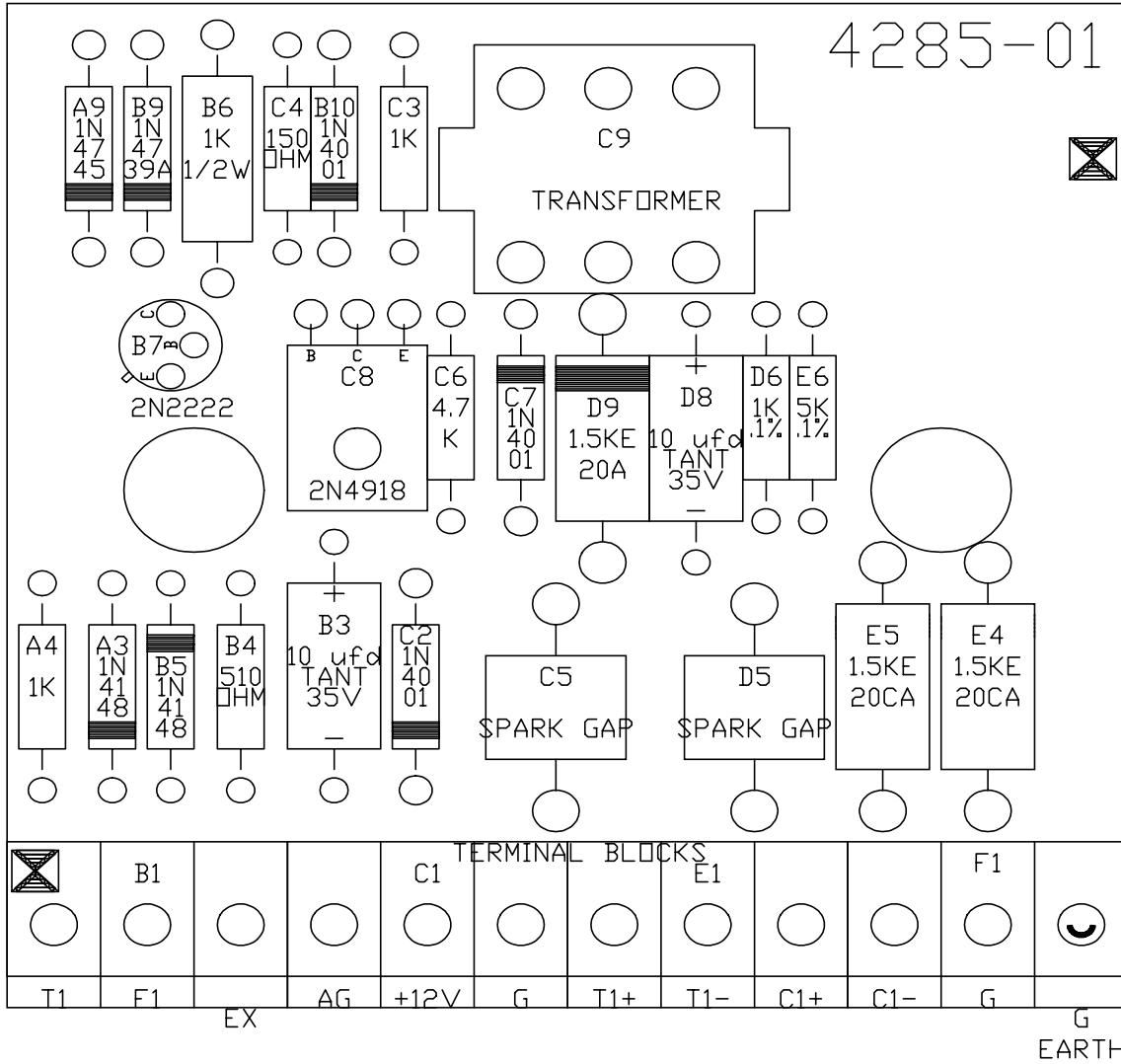


REV	DATE	APPROVED BY	DATE

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DOCUMENT NUMBER: SCH 4286-02		
 CAMPBELL SCIENTIFIC INC.		

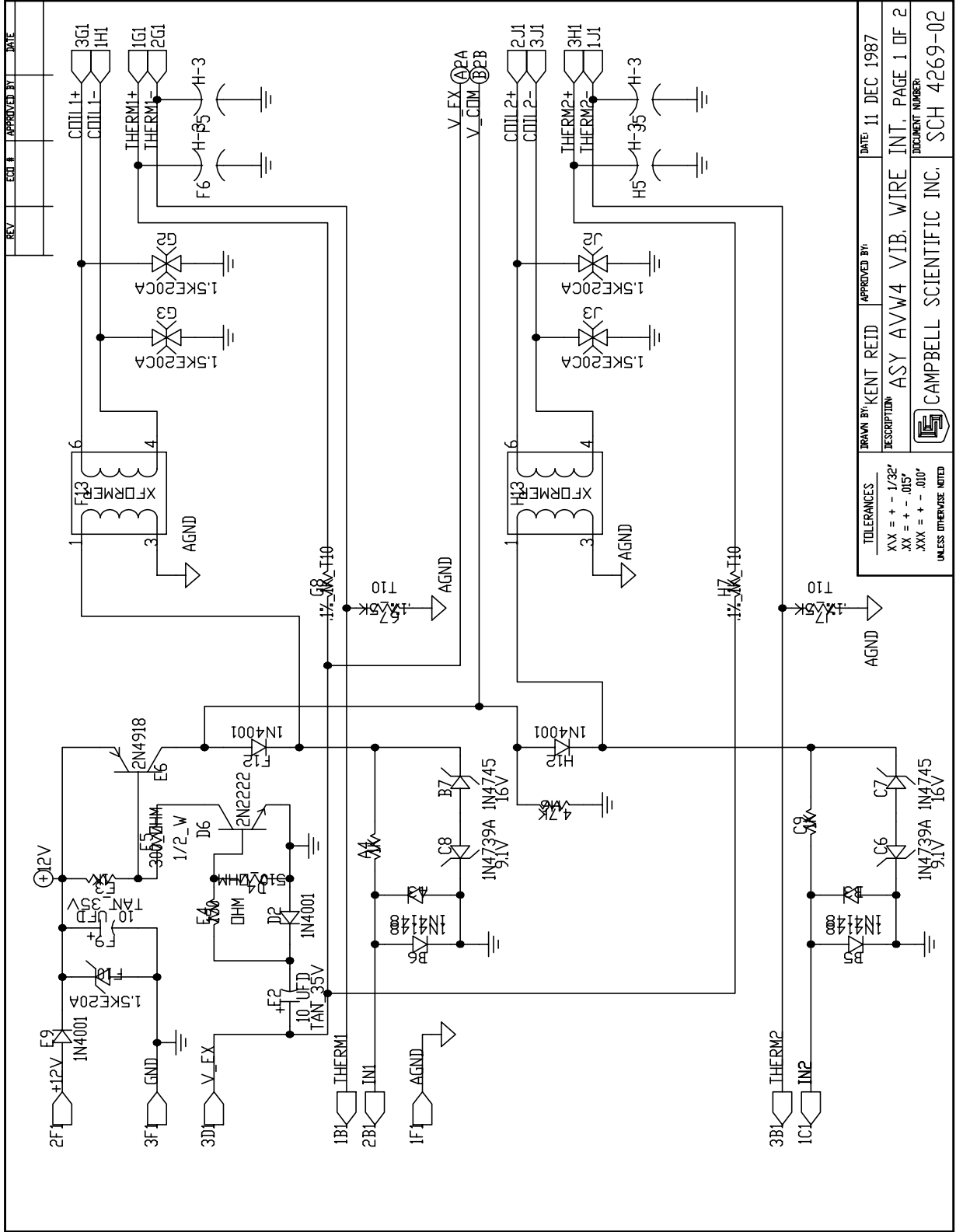
APPENDIX B. SCHEMATICS AND STUFFING CHARTS FOR AVW1 AND AVW4

4286-02 11 DEC 1987

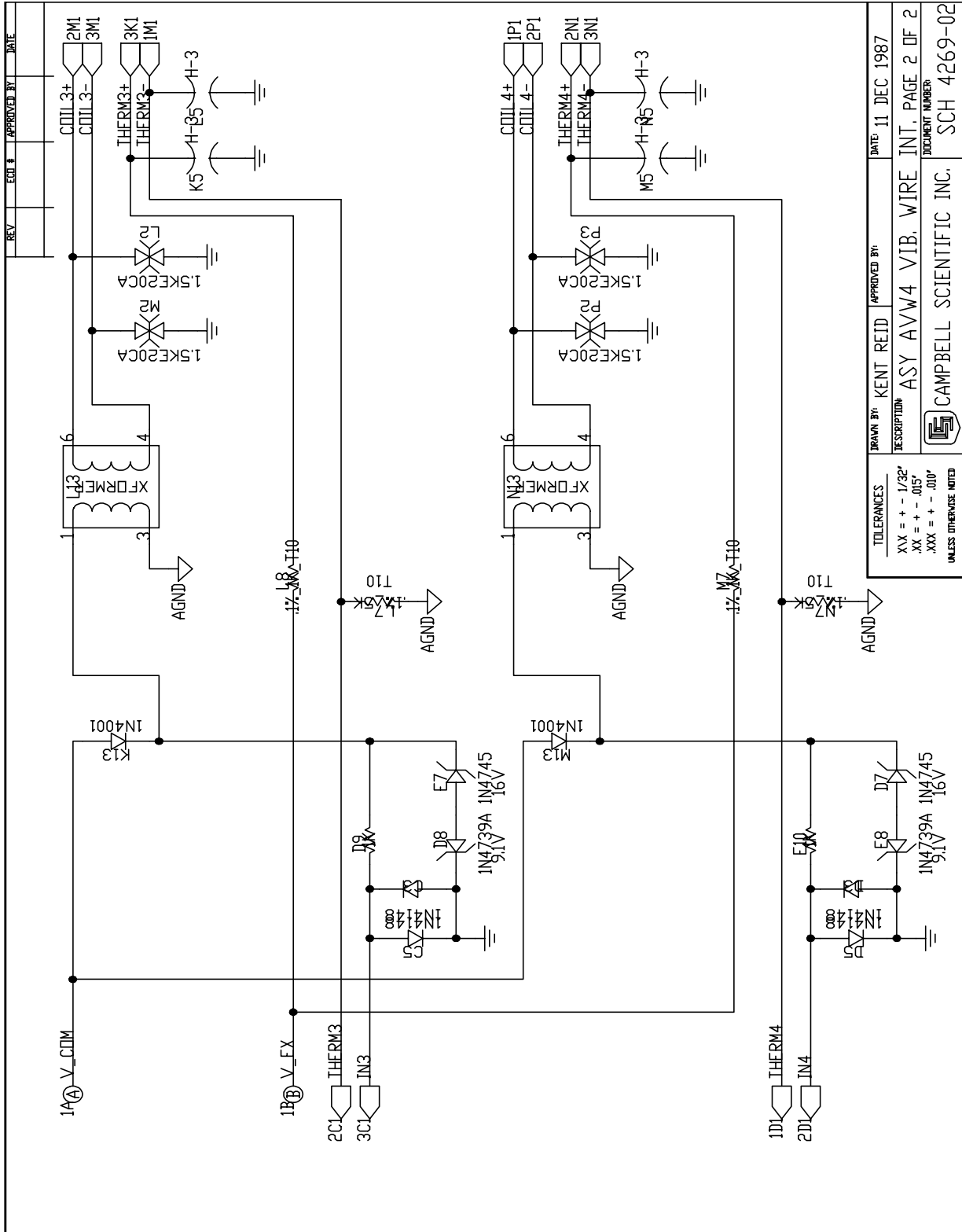


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DESCRIPTION	ASY PCS AVW1_VIB_WIRE INTERFACE				PAGE
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APPENDIX B. SCHEMATICS AND STUFFING CHARTS FOR AVW1 AND AVW4



APPENDIX B. SCHEMATICS AND STUFFING CHARTS FOR AVW1 AND AVW4



TOLERANCES	DRAWN BY: KENT REID	APPROVED BY:	DATE: 11 DEC 1987
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XX = + - .015"	DOCUMENT NUMBER		
XXX = + - .010"	CAMPBELL SCIENTIFIC INC.		
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APPENDIX B. SCHEMATICS AND STUFFING CHARTS FOR AVW1 AND AVW4

APPENDIX C. THEORY AND ADDITIONAL DETAILS

C.1 SWEPT FREQUENCY THEORY

Example: $f_2 = 31$ hundred Hz
 $f_1 = 24$ hundred Hz

$$X = (30 * f_1 * f_2) / (f_2 - f_1) \\ = 3189$$

where f_1 and f_2 are the starting and ending frequencies in hundreds of Hz respectively. One clock cycle (CC) occurs every 813.8 ns or at a rate of 1.2288 MHz.

Rule #1: $65535 > X > 256$

the 256 constraint is somehow due to an 8 bit constraint. The 65535 constraint is some limit where the swept frequency can no longer be done in exactly 15 ms.

The minimum increment in frequency is 1 clock cycle.

How many times do we have to change the half period by 1 clock cycle to cover the frequency range?

$$1 / (F_1 * 2) = 1 / (2400 * 2) = \\ .208333 \text{ ms} = \text{half period}$$

$$1 / (F_2 * 2) = 1 / (3100 * 2) = \\ .161290 \text{ ms} = \text{half period}$$

$$\text{Change in half period} = \\ .208333 - .161290 = .047043 \text{ ms}$$

of clock cycle increments to cover the .047043 ms half period range is:

$$= (.047043 \text{ ms} / .0008138 \text{ ms}) = \\ 57.81 \text{ freq. increments}$$

How much time is there between frequency increments to cover the frequency range in 15 ms?

$$\text{time} = 15 \text{ ms} / 58 \text{ frequency increments} = \\ .2586 \text{ ms/freq. incr.}$$

C.2 ADDITIONAL THEORY ON MULTIPLIER AND OFFSET

The result (X) of Instruction #28 is:

$$X = 1 / ((t \text{ ms})^2) = \\ 1,000,000 / ((t \text{ s})^2)$$

where t is the period in milliseconds. Since frequency (f) is the inverse of period, this can also be expressed as:

$$X = (f \text{ kHz})^2 = \\ [(f \text{ Hz})^2] / 1,000,000$$

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