MODEL 2721B
CHARGE AMPLIFIER

INSTRUCTION MANUAL

ENDEVCO

San Juan Capistrano, California, U.S.A.

IM2721B

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Section 1

DESCRIPTION

1.1 GENERAL

The Endevco® Model 2721B Charge Amplifier is designed for use with piezoelectric transducers with shunt resistance as low as 100 ohms and capacitance as high as 30 000 pF. The charge amplifier (shown in Figure 1-1) will accept a maximum input charge of 30 000 picocoulombs (pC) without overload, has a flat frequency response from 3 Hz to 10 kHz, decouples the ouput signal, and provides a full-scale output signal of ±10 V peak (20 V p-p) for output loads of 5000 ohms or greater. The output voltage of the charge amplifier is porportional to the transducer charge at the input. The output impedance is 10 ohms (±10%) in series with a minimum 315 uF capacitance with a maximum ±2.0 mA linear output current.

Figure 1-1. Model 2721B Charge Amplifier.

The 2721B receives a transducer's output in pC/g and converts to an output in mV/g for analyzing on readout devices. A 10-turn front-panel potentiometer with turns-counting dial allows setting transducer sensitivities from 1 to 1100 pC/g. The gain of the charge amplifier is set by a five-position switch with normalized outputs from 1 to 10 000 mV/g.

The frequency response of the 2721B can be changed (reduced) in the field with minimum effort by installing a capacitor within the unit. A front-panel switch (installed at the factory) enables the user to switch the capacitor in and out of the circuit after modification has been accomplished. Refer to paragraph 3.5 for further details.

The 2721B is designed for stand-alone operation (with an associated power supply) to provide acceleration measurements, or several amplifiers can be assembled together with a power supply for multi-channel application. Standard accessories available for use with the charge amplifier include four power supplies and a rack adapter. Refer to the "Endevco Signal Conditioners and Power Supply Requirements" chart in Section 7 for further information on the power supplies and rack adapter.

The Models 2721BM1, 2721BM2 and 2721BM3 Charge Amplifiers are identical to the 2721B except for the low frequency response and output as noted below:

Model	Flat Frequency Response	Output Scaling
2721B	3 Hz to 10 kHz	mV/g
2721BM1	1 Hz to 10 kHz	mV/g
2721BM2	3 Hz to 10 kHz	Full Scale g's
2721BM3	1 Hz to 10 kHz	Full Scale g's

1.2 INPUT POWER REQUIREMENTS

The Model 2721B series of Charge Amplifiers operate from a ±14 to ±18 V dc power source capable of supplying a minimum ±7.5 to a maximum ±9.5 mA dc supply current. Recommended power sources are the Endevco power supplies listed below. The power sources are connected to the charge amplifier via a three-pin terminal strip located on the rear panel of the unit.

This manual does not include instructions for these power supplies. An instruction manual titled "Model 422X Series Power Supplies" is used to operate and maintain the power supplies.

a. Model 4221A Power Supply
b. Model 4223 Battery Pack
c. Model 4224 Power Pack

1.3 INPUT AND OUTPUT CONNECTORS

The standard input connector supplied with each charge amplifier is a coaxial connector with 10-32 threads. An optional (T-option) BNC type connector is installed as the input connector if T-option is specified on the customer Purchase Order. The input is single ended with one side connected to circuit common and case, and should not be shunted with less than 1 000 ohms of impedance nor greater than 30 000 pF capacitance.

The output connector is a standard BNC type and is single ended with one side connected to circuit common and case. The output impedance is 10 ohms (±10%) in series with at least 315 uF (or greater) capacitance.

Section 2

INSPECTION AND INSTALLATION

2.1 INSPECTION

The charge amplifier is packed in protective bags and packaged in shipping cartons containing shock-absorbent materials to prevent in-transit damage. However, upon receipt of the units, the customer should make an inspection to be certain that no damage has occurred during shipment. Obvious damage should be reported immediately to the carrier.

Inspect the contents of the shipping carton and verify that a hardware kit (Endevco part 21732) is included in the shipment with each charge amplifier. The kit consists of:

Quantity	Item	Endevco Part Number
4	Nylon mounting screws, #4-40 x 1/4	EH200
4	Adhesive-mount rubber bumper feet	EHR77

2.2 INSTALLATION

The charge amplifier case is drilled with eight holes (four each side) for bolting two or more charge amplifiers together during operation or to an associated power supply. Four of the holes on one side are tapped with #4-40 threads, and the four holes on the opposite side are clearance holes for inserting mounting screws to mechanically link the units together. Adhesive-backed rubber feet are supplied to install on the four corners of the charge amplifier base to prevent movement during bench operation.

The charge amplifier can also be installed in a Model 4914A Rack Adapter for 19-inch rack applications. The optional rack adapter is capable of holding up to nine signal conditioners and one power supply. The exact quantity varies depending on the type of power supply used. Refer to the "Endevco Signal Conditioners and Power Supply Requirements" chart in Section 7 for appropriate quantities. Perform the following steps if the signal conditioner is to be mounted in the optional rack adapter:

a. If applicable, remove the rubber feet from all units to be installed in the rack adapter.

b. Loosen the five Phillips-head screws holding the front retaining rail on the rack adapter.

c. Slide the units in the rack adapter, raise the retaining strip and tighten the five screws.

d. The Model 2914A Rack Adapter is mounted in a 19-inch rack using the hardware supplied with the rack adapter.

CAUTION

Prior to connecting a transducer assembly and cable to charge amplifier, always place a short between the cable's center conductor and shell to eliminate any stored charge.

e. Connect transducer cable to INPUT connector J1 on rear panel of amplifier.

f. Connect monitoring device to OUTPUT connector J2 on rear panel of amplifier.

g. Connect power supply output to the three-terminal barrier strip on rear panel of nearest charge amplifier. Observe polarity when connecting power supply.

h. Connect power to remaining amplifiers as shown in Figure 2-1. Connection consists of parallel wiring as shown in the figure. Standard 22 AWG insulated hookup wire is sufficient for interconnecting the power between the units. Source supply is ±15 V ±5% at 9.5 mA maximum per unit. Each amplifier power input line is diode-protected against accidental polarity reversal. The units are not fused, therefore care should be exercised to avoid exceeding the plus and minus 18 V limit if other than Endevco power supplies are used.

i. Charge amplifiers are ready for operation.

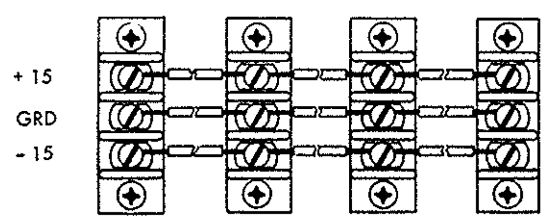

Figure 2-1. Multiunit Power Interconnection.

2.3 GROUNDING

The amplifier chassis and power common are connected to signal return. Isolated accelerometers or isolating studs are recommended.

Section 3

OPERATION

3.1 GENERAL

This section describes the functions of the controls and connectors of the charge amplifier, briefly defines characteristics of the unit to be considered before operation, and provides instructions for using the charge amplifier. Users of the charge amplifier should review this section in its entirety prior to operating the charge amplifier.

3.2 CONTROLS AND CONNECTORS

All operating controls for the charge amplifier are located on the front panel as shown in Figure 3-1. Connectors for hookup are contained on the rear panel. Table 3-1 provides a listing of the controls and connectors and function of each.

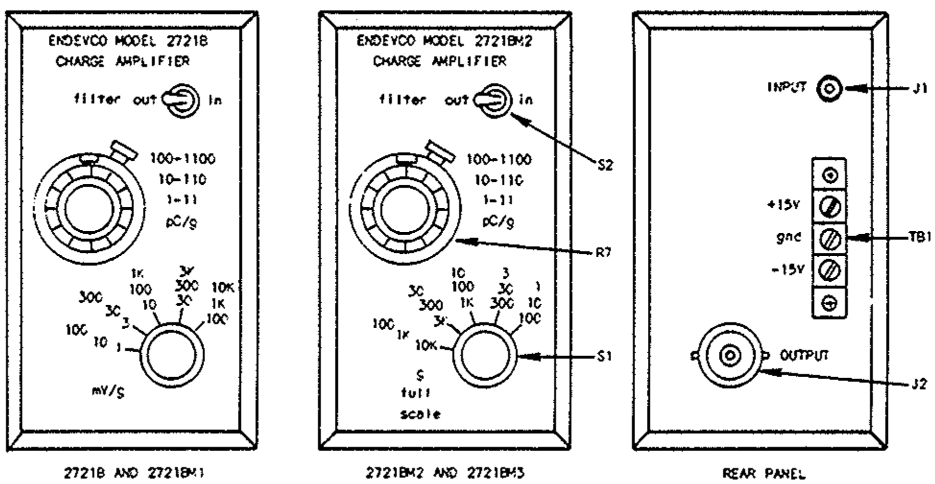

Figure 3-1. Front and Rear Panel Views of the Charge Amplifier.

TABLE 3-1. CHARGE AMPLIFIER CONTROLS AND CONNECTORS.

Control/Connector	Ref Des	Function
FILTER IN/OUT Switch	S2	A 2-position switch to enable user to switch a low-pass filter in or out of circuit. When switch is set to IN position a capacitor (C13) is added to amplifier output circuit to reduce bandwidth and eliminate noise. See paragraph 3.5. Capacitor C13 is optional, thus, component is supplied and installed by user.
Sensitivity Control 1-11/10-110/100-1100 pC/g	R7	A calibrated 10-turn potentiometer used to normalize system sensitivity. Control has dial mechanism and dial lock to set and lock-in amplifier sensitivity. <u>Dial Mechanism</u>: Number shown in window is most significant digit. Second and third digits are on inner dial under center line of window. <u>Dial Lock</u>: When set, immobilizes dial to prevent unintentional changes in dial setting. <u>2721B and 2721BM1</u>: Green range scale (100-10K) is used with green gain setting on mV/g gain selector switch. Red range scale (10-110) is used with red gain settings on mV/g gain selector switch. Black range scale (1-11) is used with black gain settings on mV/g gain selector switch.

TABLE 3-1. CHARGE AMPLIFIER CONTROLS AND CONNECTORS (CONT'D).

Control/Connector	Ref Des	
		2721BM2 and 2721BM3: Green range scale (10-110) is used with green gain settings on g FULL SCALE gain selector switch. Red range scale (10-110) is used with red gain settings on g FULL SCALE gain selector. Black range scale (1-11) is used with black gain settings on g FULL SCALE gain selector switch.
Gain Selector Switch mV/g or g FULL SCALE	S1	A 5-position rotary switch used to select charge amplifier's gain in mV/g for Models 2721B and 2721BM1, and in full scale g's for Models 2721BM2 and 2721BM3. Switch has three range settings: Green range for high sensitivity transducers (100-1100) pC/g). Red range for medium sensitivity transducers (10-110) pC/g). Black range for low sensitivity tranducers (1-11 pC/g). 2721B and 2721BM1: Green gain settings (100-10K) are used with green range scale on pC/g sensitivity control.

TABLE 3-1. CHARGE AMPLIFIER CONTROLS AND CONNECTORS (CONT'D)

Control/Connector	Ref Des	Function
		Red gain settings (10-1K) are used with red range scale on pC/g senstitivity control. Black gain settings (100-10K) are used with black range scale on pC/g sensitivity control.
INPUT Connector	J1	A 10-32 threaded coaxial connector used for mating most Piezoelectric transducer cables (e.g., Endevco 3000 Series) to charge amplifier. Optional connector is a standard BNC if specified by customer.
OUTPUT Connector	J2	A standard BNC coaxial connector used for hookup to a monitoring device, such as an oscilloscope.
-15/GRD/+15 Terminal Strip	TB1	A three-pin terminal barrier strip for connecting input power to amplifier.

3.3 OPERATING CONSIDERATIONS

The frequency response and maximum residual-noise level of the charge amplifier are characteristics that should be considered prior to using the charge amplifier. In addition, the measurements of very low-level inputs are a consideration since residual noise will affect the lowest signal to be measured. These areas of concern are briefly defined in paragraphs 3.3.1 through 3.3.3.

3.3.1 FREQUENCY RESPONSE

The frequency response (factory set at 10 kHz) of the charge amplifier is a function of the impedance as seen by the input to the amplifier (i.e., the impedance of the transducer and cable). The response is defined as follows:

Frequency Response (±5%)	Input Shunt Resistance	
1 Hz to 10 kHz	≥ 300 k ohms	2721BM1/2721BM3
3 Hz to 10 kHz	≥ 100 k ohms	2721B/2721BM2
3 Hz to 10 kHz	100 k to 300 k ohms	2721BM1/2721BM3
5 Hz to 10 kHz	10 k to 300 k ohms	All
50 Hz to 10 kHz	1 k to 10 k ohms	All

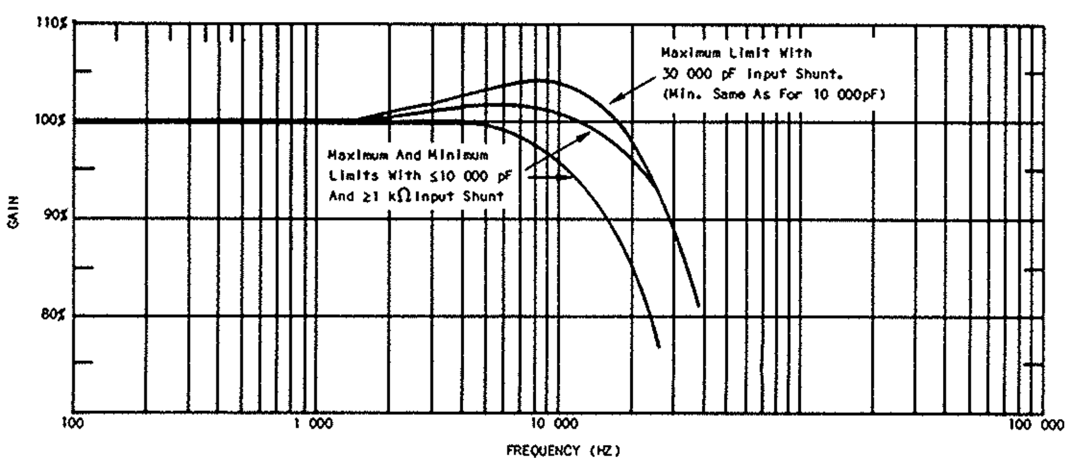

Figure 3-2. High Frequency Response Versus Source Loading.

3.3.2 RESIDUAL NOISE

When measuring low-level signals and the source capacitance is significant, it is desirable to know the maximum anticipated residual noise from the amplifier. The residual noise for the Model 2721B as a function of capacitive and resistive shunt will be less-than-or-equal-to the following formula referred-to-input (RTI):

$$Q_{noise}\ (rms) = \leq \sqrt{Q_a^2 + Q_b^2}$$

where Q_a = 0.03 pC rms + 0.008 pC rms/1000 pF of input shunt capacity

$$Q_b = \frac{100}{\sqrt{|Rs|}} = \text{pC rms (for shunt resistance} \leq 100\text{ k ohm)}$$

Or residual noise of 100 uV rms referred-to-output (RTO), whichever is greater between RTI and RTO. The RTO is a constant factor due to charge amplifier noise.

3.3.3 LOW-LEVEL MEASUREMENT

The measurement of very low-level inputs requires a knowledge of the residual-noise level of the system, since it is this noise level that will limit the lowest signal that can be measured. The noise level of the system is best understood and most useful when expressed in equivalent units of the measurand (g, psi, lbs, etc.). An example of noise calculation is shown below:

Assume that an Endevco Model 2217E Accelerometer with a sensitivity of 40.0 pC/g and capacitance of 350 pF is to be used with a 500-foot cable, 30 pF per foot, to measure a low acceleration signal. The amplifier sensitivity dial is set to 40 and the gain control is set to red scale 1K mV/g for 2721B and 2721BM1 (red scale 1K g FULL SCALE for 2721BM2 and 2721BM3).

The noise of the amplifier depends on total source capacitance. This is the sum of 350 pF transducer capacitance plus cable capacitance of 15 000 pF, or a total of 15 350 pF. The noise in picocoulombs is:

$$\text{Noise} = 0.03 + (0.008 \times 15.35)\ \text{pC rms}$$
$$= 0.1528\ \text{pC rms}$$

Since the noise is random, multiply the rms value by a crest factor of three to obtain a peak value:

$$\text{Noise} = 3 \times 0.1528 \text{ pC rms} = 0.4584 \text{ pC pk}$$

The equivalent noise in engineering units is equal to the noise in picocoulombs divided by the transducer sensitivity:

$$\text{Equivalent noise} = \frac{0.4584 \text{ pC pk}}{40.0 \text{ pC/g}} = 0.0115 \text{ g pk}$$

The resistance of the transducer is 20 000 megohms minimum. The noise of the amplifier due to resistive loading is:

$$\text{Noise} = \frac{100}{\left|\sqrt{2 \times 10^{10}}\right|} = .000707 \text{ pC rms}$$

In the preceding example the noise contributed by the input capacitance is much greater than the the noise contributed by the input resistance. The input resistance can, therefore, be ignored.

The maximum RTO noise is 100 uV rms. Since the amplifier gain setting provides 1000 mV/g, the equivalent RTO noise is:

$$\text{RTO Noise}_{rms} = \frac{100 \text{ uV rms}}{1000 \text{ mV rms/g}}$$

$$= 0.0001 \text{ g rms}$$

$$\text{RTO Noise}_{pk} = 3 \times 0.0001 \text{ g rms}$$

$$= 0.0003 \text{ g pk}$$

Comparing RTI noise to RTO noise we find that RTI of 0.0115 g pk is much greater than RTO of 0.0003 g pk. Therefore, the RTI noise will determine the minimum acceleration that can be measured.

In actual application, the signal-to-noise ratio should be at least 3:1 to provide a noise-free signal level. Thus, with a 0.115 g pk noise level, the minimum acceleration that can be measured is 3 x 0.0115 g pk, or 0.0345 g pk. However, since these noise calculations are based on maximums, actual test results may possibly indicate even lower readings are obtainable. Also, since the noise specification is based on wideband noise over the entire frequency spectrum of the charge amplifier, the signal-to-noise readings can be improved by narrow-band filtering the output signal to the area-of-interest. The amount of improvement is dependent on the bandwidth of interest, but can be of an order of magnitude in many cases.

3.4 OPERATING INSTRUCTIONS FOR A TYPICAL APPLICATION

The charge amplifier is frequently used in laboratory applications to obtain shock and vibration data on test specimens. Equipment necessary to perform a test is a transducer with a known calibrated sensitivity, a readout device to analyze the shock and vibration data, a charge amplifier to interface the transducer to the readout device, and a shaker table to provide the required acceleration to the test specimen.

Devices such as oscilloscopes, oscillographs (for hard-copy printouts), digital voltmeters, etc., can be used as readout instruments to analyze the shock and vibration data. These instruments are selected according to customer preference. The test presented in this typical application will use an oscilloscope as the readout device to monitor the ac output. An Endevco Model 2217E Accelerometer, with a typical charge sensitivity of 40 pC/g, will be used as the transducer to detect the acceleration applied to the test specimen. The charge amplifier used in this example will be a Model 2721B.

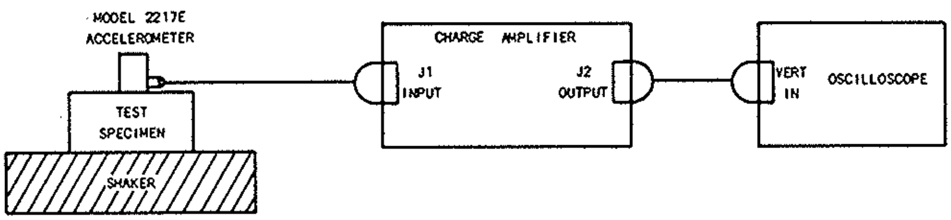

Figure 3-3. Typical Application Test Set-Up.

a. Connect equipment as shown in Figure 3-3 with the transducer mounted to test specimen in the axis of interest. Endevco cables are strongly recommended to minimize cable- related errors which might reduce measurement accuracy. The cable capacitance does not affect gain accuracy of the charge amplifier.

b. Engergize equipment and allow 15 minutes to temperature stabilize.

c. Normalize the system (accelerometer and charge amplifier) by performing the following steps:

1. Note the charge sensitivity expressed in pC/g on the calibration card supplied with the accelerometer. Assume the charge sensitivity is 40 pC/g for this test.
2. Rotate the pC/g sensitivity dial (R7) on the charge amplifier until the numeral 4 appears in the window and 0 (zero) alines immediately below 4 in the window. This dial setting indicates 40.0 pC/g, the charge sensitivity of the Model 2217E Accelerometer used in this example.
3. Press dial lock-lever down to lock the dial in place.
4. The system is now normalized. The charge amplifier has been set to the 40.0 pC/g charge sensitivity of the 2217E accelerometer.

d. Set the mV/g gain switch to the desired range. The g level input required to produce a 10.00 V pk full-scale output can be determined by the following formula, or by referring to Table 3-2. Table 3-2 is to be used for the 2721B and 2721BM1.

$$\text{Peak g Input} = \frac{\text{Maximum Full-Scale Output}}{\text{Amplifier mV/g Range Setting}}$$

As an example, since the sensitivity of the 2217E Accelerometer is assumed to be 40 pC/g, the charge amplifier is normalized in Step c. by using the 10-110 pC/g red scale on sensitivity control R7. Thus, the 10 to 1K red scale on the mV/g range switch S1 is used to select the desired range for a 10.00 V pk full-scale output. If S1 is set to 1K mV/g position on the red-scale range, a 10 g pk input is required to provide a 10.00 V pk full-scale output. See Table 3-2 or use the formula above.

Calculating the full-scale output for the 2721BM2 and 2721BM3 is not necessary since each setting of the g FULL SCALE switch S1 indicates the charge amplifier's full scale output in g's.

e. The vibration test on the test specimen is ready to be performed. Energize shaker and apply the appropriate sinusoidal motion to test specimen. A full-scale output (10 V pk or 20 V p-p) of the charge amplifier will occur when a 10 g pk acceleration force is applied to test specimen, if using the 1K red scale noted in Step d.

TABLE 3-2. MAXIMUM PEAK G INPUT FOR 10 V PEAK FULL-SCALE OUTPUT.

(MODELS 2721B AND 2721BM1)

Transducer Sensitivity (pC/g)		**Maximum g Input (pk)/Gain Setting (mV/g)				
0.1 to 1.10	Max g	100 000 g*	33 000 g*	10 000 g	3 333 g	1000 g
	Gain	0.1	0.3	1	3	10
1.0 to 11.0	Max g	10 000 g*	3 300 g*	1000 g	333 g	100 g
	Gain	1	3	10	30	100
10 to 110	Max g	1000 g*	330 g*	100 g	33 g	10 g
	Gain	10	30	100	300	1K
100 to 1100	Max g	100 g*	33 g*	10 g	3.3 g	1 g
	Gain	100	300	1K	3K	10K

* Limited to pC/g x g's Input = 30 000 pC Maximum Input

** Peak Full Scale Output = Maximum Peak g Input x Gain Setting in mV/g = 10.00 V pk

3.5 MODIFYING FREQUENCY RESPONSE

The charge amplifier, as shipped, has a high frequency -5% point of 10 kHz. This frequency is determined by capacitor C11 in the output amplifier feedback loop. The frequency can be changed in the field by installing a selected capacitor (C13) in parallel with C11 to reduce the frequency response to the desired level when C13 is switched into the circuit. Table 3-3 and Figure 4-3 provide a guide in the selection of C13. A mylar type capacitor is recommended with a working voltage of 50 V or higher, typically 100 V. Capacitor values are typical, thus, the unit should be tested for precise frequency.

A FILTER ON/OFF switch on the front panel of the charge amplifier has been factory installed to enable the user to switch C13 in and out of the circuit. The capacitor is an option item and is supplied and installed by the user. Drawing 2721B-1C and 2721B-501C are to be used as an installation guide if the component is to be installed.

TABLE 3-3. LOW-PASS FILTER CAPACITOR SELECTION.

±5% Point	C13 (pF)	±5% Point	C13 (pF)
5 kHz	170	500 Hz	2 600
2 kHz	530	200 Hz	5 800
1 kHz	1100	100 Hz	11 800

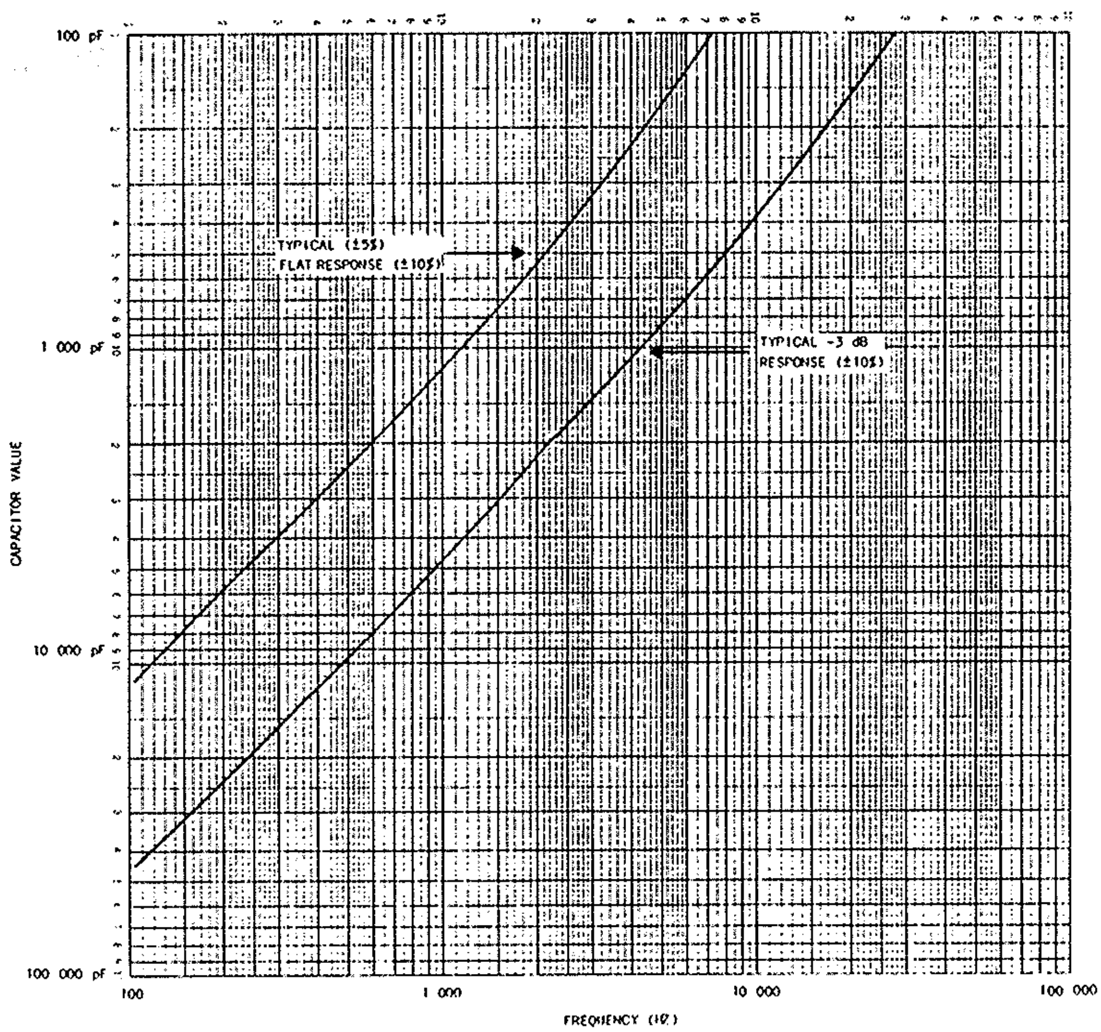

Figure 3-4. Typical Filter Capacitor Value Versus Frequency.

Section 4

THEORY OF OPERATION

This section provides the functional theory of operation for the Model 2721B series of Charge Amplifiers. The circuitry for the series of charge amplifiers is identical for all units, only certain component values are changed. These components are C7, C10, R2, R10 and R11. The functional block diagram shown in Figure 4-1 is for the 2721B, but is typical for all units. Users should refer to the applicable charge amplifier schematic for proper component value and gain switch setting. The gain switch settings shown in Figure 4-1 represent the 2721B and 2721BM1. Drawings included in this section are for reference only and are provided as a supplement to the complete schematic drawings Section 7 of this manual.

In paragraphs 4.1 through 4.4, the sensitivity control settings are limited to 1-11 pC/g range, and control settings are limited to the 1, 3, 10, 30 and 100 mV/g settings (indicated by the markings in black on the front panel).

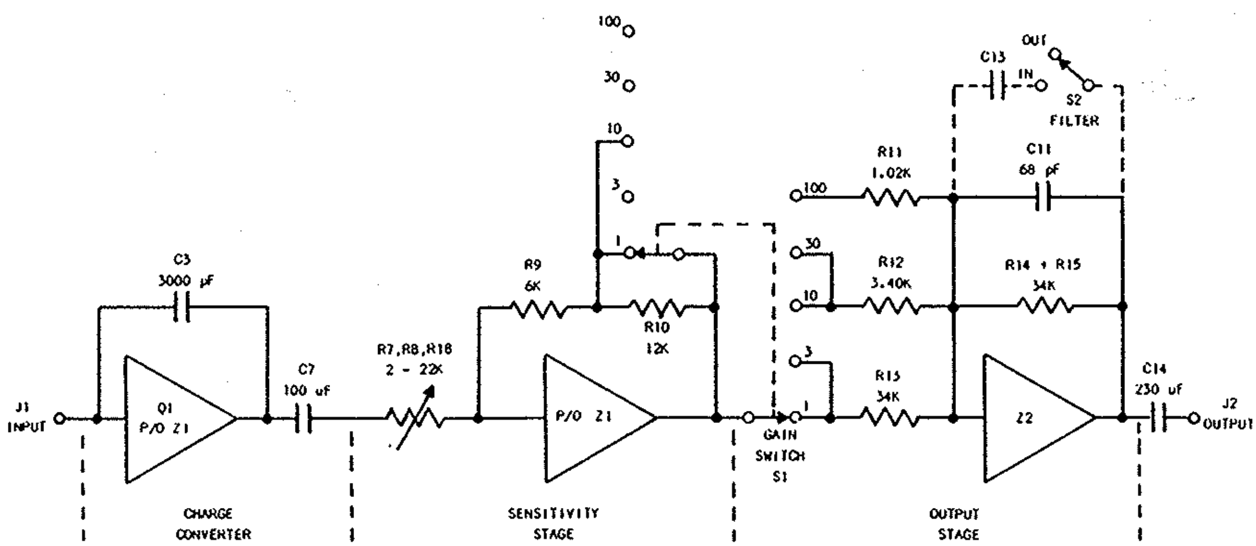

Figure 4-1. Typical Charge Amplifier Functional Block Diagram.

4.1 CHARGE CONVERTER

The charge converter (Figure 4-1) has a set conversion ratio of 0.333 mV/g. The converter is analogous to an inverting operational voltage amplifier, but capacitive feedback is used to set the closed-loop gain instead of resistance.

The charge conveter consists of a high-gain operational amplifier wired in an inverting mode with a large amount of capacitance (3000 pF) in its negative feedback loop. The amplifier is specifically designed to interface with piezoelectric devices and converts the picocoulomb charge ouput of these devices into a proportional voltage level. The effective transfer function of the charge converter is:

$$\frac{E_o}{Q} = \frac{-1}{C_f}$$

where E_o = the output signal in volts

Q = the input charge in pC

C_f = the charge converter feedback capacitor in pF

Example:

An accelerometer with a charge sensitivity of 3 pC/g undergoing an acceleration force of 2 g's is attached to the input of the charge converter. The output of the converter is:

$$E_o = \frac{-Q}{C_f} = \frac{-3 \times 2}{3000} = -0.002 \text{ volts, or } -2 \text{ mV}$$

The input impedance of the converter appears to the signal source as a very high value of capacitance (approximately equal to the value of feedback capacitance C_f times the open-loop gain of the amplifier). This high value of capacitance effectively swamps capacitance changes from the input source. For this reason, changes of input cable, or changes of capacitance of the transducer due to temperature fluctuation, have no appreciable effect on the overall gain of the system.

The circuit of the charge amplifier is shown simplified in Figure 4-2. Referring to the figure, the charge-converter components include a common-source FET input stage (Q1) driving one-half of dual operational amplifier (Z1). The signal feedback network consists of parallel-connected capacitor C3 and resistor R2. The RC time constant of C3 and R2 determine the low frequency response of each charge amplifier.

The input signal is applied through connector J1, passes through dc decoupling capacitor C1, and is applied to the gate of Q1. The signal is inverted by this stage and fed to the non-inverting (+) input of the operational amplifier. The signal is amplified by Z1 and fed through C3 back to the input. The quiescent dc output level of the operational amplifier Z1, adjusts itself to within a few volts minus, referenced to common. This level is the result of two voltage feedback loops for dc stability. One loop consists of a voltage divider (R4 and R6) which controls the reference voltage applied to the inverting (-) input of the operational amplifier Z1. The second loop is resistor R2 which controls the bias applied to Q1. Capacitor C5, connected between the inverting input of Z1 and common, filters out the ac component. The charge converter output signal is dc decoupled through C7 and fed to the input of the sensitivity stage.

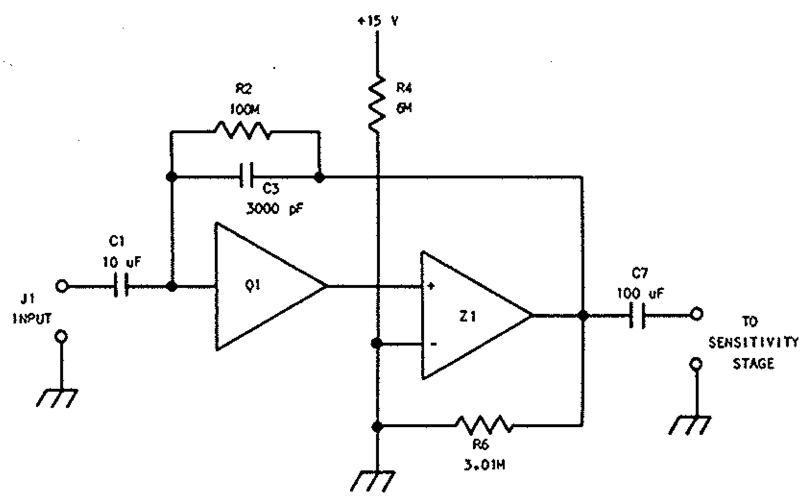

Figure 4-2. Charge Converter Simplified Schematic.

4.2 SENSITIVITY STAGE

The second stage is an inverting variable-gain voltage amplifier that is used for normalizing (standardizing) the total amplifier to transducers with sensitivities of from 1 to 1100 pC/g.

The sensitivity stage is an opertional amplifier wired in an inverting mode with a resistive network in the feedback loop and a resistive input network. The transfer function of this stage is:

$$\frac{E_o}{E_{in}} = \frac{-R_{fb}}{R_{in}}$$

where R_{fb} = the feedback resistance network

R_{in} = the input resistance network

The sensitivity stage performs two functions. First, it provides a variable gain, adjustable in known increments with the front-panel sensitivity control; and second, it operates in conjunction with the gain control switch on the front panel to generate step gains of 3 and 9.

As previously stated, the variable-gain portion of the stage is used to compensate for the variations that exist between the charge sensitivities of various transducers that can be used with the charge amplifier. This portion of the circuitry is designed to produce a gain component that is inversely proportional to the setting of the sensitivity control (e.g., sensitivity control settings of 1, 5, 10 produce gain components of 1, 0.2 and 0.1). The step-gain portion is used in conjunction with the output stage to produce the gain settings available with the front-panel gain switch S1. The gain for the 2721B and 2721BM1 is in mV/g, and in g FULL SCALE for the 2721BM2 and 2721BM3.

The circuitry of the sensitivity stage for the 2721B and 2721BM1 consists of the second half of the operational amplifier Z1, a switch-selectable feedback resistance of 6 k ohms or 18 k ohms, and an input resistance variable from 2 k ohms to 22 k ohms. Capacitors C9 and C10 provide frequency roll-off for the stage. The 2721BM2 and 2721BM3 are identical to the 2721B except for the values of R10 and C10.

Example:

Continuing the example in paragraph 4.1, the sensitivity control for the accelerometer used would be set to 3 pC/g and the signal appearing at the input of the sensitivity stage is -2 mV. With the gain control set at 100 the output of the sensitivity stage is:

$$E_o = \frac{E_{in} \cdot R_{fb}}{R_{in}} = \frac{-2 \times 10^{-3} \times 18 \times 10^3}{6 \times 10^3}$$

$$E_o = -6 \text{ mV}$$

4.3 GAIN STAGE

The gain stage is an operational amplifier wired in an inverting mode, with the same transfer function as the sensitivity stage. The gain stage provides three step gains of 1, 10 and 33.3 (or 30.1), selected by the front-panel gain switch S1. The 2721B and 2721BM1 have gains of 1, 10 and 33.3, and gains for the 2721BM2 and 2721BM3 are 1, 10 and 30.1.

The gains are established by the ratios of R11, R12 and R13 to the total resistance of R14 plus R15 (approximately 34 k) as defined below. The black scale (1, 3, 10, 30 and 100) on the 2721B or 2721BM1 gain switch S1 is used in the examples. Substitute black scale 10K, 3K, 1K, 300 and 100 if a 2721BM2 or 2721BM3 is used.

a. A gain of 1 is obtained when gain switch S1 is set to 1 or 3 position. This selects the ratio of R13 to R14 + R15 (34 k to 34 k). A ratio of 1 to 1.
b. A gain of 10 is obtained when S1 is set to 10 or 30 position. This selects the ratio of R12 to R14 + R15 (3.40 k to 34 k). A ratio of 10 to 1.
c. A gain of 33.3 is obtained when S1 is set to 100 position. This selects the ratio of R11 to R14 + R15 (1.02 k to 34 k). A ratio of 33.3 to 1. For the 2721BM2 and 2721BM3, the gain is 30.1 since R11 has a value of 1.13 k.

Potentiometer R15 is an adjustment to compensate for any error in the gain stage ratios. The potentiometer is adjusted during calibration to center the ratio errors between R11, R12 and R13 to the total resistance of R14 + R15. After adjustment, the total resistance of R14 + R15 will be approximately 34 k ohms.

The gain circuitry consists of operational amplifier Z2, a 34.0 k ohm feedback loop and three input resistances selectable with the gain control switch. The resistor used for each setting is shown in Figure 4-1.

Example:

To complete our example, the signal applied to the input of this circuit is 6 mV. The gain control is set at 100 so that the output of the gain stage is:

$$E_o = \frac{-E_{in} \cdot R_{fb}}{R_{in}} = -\frac{6 \times 10^{-3} \times 34 \times 10^{3}}{1.02 \times 10^{3}}$$

$E_o = -2.00 \times 10^{-3}$, or 200 mV at the output of the charge amplifier for an input acceleration of 2 g's.

The final output stage has two bifercated terminals to permit the user to install a capacitor (C13) that converts this stage into a single-pole filter to lower the upper -3 dB point of the amplifier's frequency response. The capacitor, when installed, parallels capacitor C11, and a front-panel switch (FILTER IN/OUT) is used to disconnect this capacitor so the amplifier's full bandwidth can be restored.

The final stage is capable of 10 V pk (minimum) signal swings at all sensitivity settings and range positions when ouput loads are a minimum of 10 k ohms.

4.4 INPUT VOLTAGE

The input voltage to the charge amplifier from an accessory power supply is routed through the terminal block TB1. Diodes CR1 and CR2 prevent inadvertent polarity reversal from destroying the amplifier's internal components.

Section 5

MAINTENANCE

This section contains procedures for calibrating, checking the operation, and fault isolation of the 2721B Series of Charge Amplifiers. The operational check can be used for incoming inspection or for determining if calibration is required. The procedures are prepared for the 2721B and 2721BM1, but are to be used for the 2721BM2 and 2721BM3. A statement is included for clarity where the gain switch settings differ. The gain switch for the 2721B and 2721SM1 is in mV/g, and in g FULL SCALE for the 2721BM2 and 2721BM3.

5.1 REQUIRED EQUIPMENT

Table 5-1 lists the test equipment, or equivalent, required to perform the tests. Test equipment or accessories specified in the table by manufacturer and model number meet or exceed the minimum requirements. However, equivalent equipment which meets the minimum use specification can be used.

Cables, connectors, switches, etc., are listed as an aid for interconnecting the test setups shown in these procedures. Other methods, which perform the same functions and do not introduce ground loops can be used.

TABLE 5-1. REQUIRED TEST EQUIPMENT.

Item	Minimum Use Specification	Manufacturer/Model
Oscillator	3 Hz, 100 Hz, 10 kHz variable output	Wavetek 171
Power supply	±15 V at 10 mA	Endevco 4221A
Rms Voltmeter	0.6% accuracy (10 V scale) 3 Hz, 100 Hz, 10 kHz	Bruel and Kjaer
Oscilloscope	3 Hz to 10 kHz, 100 uV/div.	Tektronix 531A
Capacitor	1000 pF shielded (value known to 1 pF	Endevco 2947B-4
Resistor	100 ohms 0.1% non-inductive	Any
Resistor	900 ohms 0.1% non-inductive	Any
Attenuator	1000 ohm multiturn potentiometer	E.S.I DP 1211
Switch (2 req)	SPDT	Any

5.2 INPUT SIGNAL INFORMATION

In Figure 5-1, a charge input signal is produced by applying an ac voltage to the amplifier input through a known value of capacitance. The chage (Q) seen by the amplifier input is equal to:

$$Q = \frac{EC}{1000}$$

where E is the voltage signal in mV

C is the capacitance in pF

When the capacitance is precisely 1000 pF, Q in picocoulombs is equal to the input signal in mV. This is convenient because the mV input accuracy is easy to verify and input and output values are the same.

The procedures outlined herein are designed for a test setup having precisely 1000 pF of capacitance in series with the ac signal source. If the capacitance is not 1000 pF, the input signal from the ac source must be multiplied by a constant (K) which is determined by the following equation:

$$K = \frac{1000}{C}$$

where C is the actual value of series capacitance

Example: A series capacitor or 997.4 pF is used

$$K = \frac{1000}{997.4} = 1.0026$$

An input of 7.07 volts becomes 7.07 x 1.0026 = 7.088 or 7.09 to three-place accuracy. Each input indicated in the procedures would be multiplied by 1.0026 to generate the output signals shown.

5.3. PRELIMINARY SET-UP

a. Connect equipment as shown in Figure 5-1. All signal leads must be shielded. Ensure that only one point of test setup is grounded to prevent ground loops.

b. Preset charge amplifier controls as follows:

1. Set pC/g sensitivity control to 1.00 (ccw).
2. Set mV/g gain control to 1 (or g FULL SCALE control to 10K).
3. Set FILTER IN/OUT switch to OUT.

c. Apply power to equipment and allow 15 minutes to temperature stabilize.

5.4 FULL SCALE TEST

This test verifies the charge amplifier's output swing is within specification. Test setup is shown in Figure 5-1. The conditions of paragraph 5.2 apply.

a. Adjust signal generator for 10 V pk (7.07 V rms) at 100 Hz.
b. Verify an output signal on rms meter of 10 V pk (7.07 V rms).
c. Verify output waveform on oscilloscope is undistorted and exhibits no clipping.

5.5 SENSITIVITY CONTROL ACCURACY TEST

This test verifies the charge amplifier's pC/g sensitivity control is operating within specification. Test setup is shown in Fugure 5-1. The conditions of paragraph 5.2 apply.

a. Apply an input signal of 7.07 V rms at 100 Hz.
b. Verify an output of 7.07 V rms ±1% (7.00 to 7.14 V rms), and record value.
c. Adjust pC/g sensitivity dial control to 10.0.
d. Multiply measured rms voltage output by ten and record product.
e. Verify recorded values obtained in Steps b and d are within 0.5%.

5.6 GAIN ACCURACY TEST

This test verifies the charge amplifier's mV/g gain control (or g FULL SCALE control) is operating within specification. Test setup is shown in Figure 5-1. The conditions of paragraph 5.2 apply. The test steps are given in Table 5-2. Input frequency is 100 Hz. Apply the input and adjust controls as indicated. Verify the output level shown for each step.

TABLE 5-2. GAIN ACCURACY CHECK.

Step	Input V rms		Gain Switch		Sensitivity Control	Output V rms	Tolerance (±1.5%)
	2721B 2721BM1	2721BM2 2721BM3	2721B 2721BM1	2721BM2 2721BM3			
1	7.07	7.07	1	10K	1.00	7.07	6.96 to 7.18
2	2.36	2.12	3	3K	1.00	7.07	6.96 to 7.18
3	0.707	0.707	10	1K	1.00	7.07	6.96 to 7.18
4	0.236	0.212	30	300	1.00	7.07	6.96 to 7.18
5	0.0707	0.0707	100	100	1.00	7.07	6.96 to 7.18

5.7 FREQUENCY RESPONSE TEST

This test verifies the frequency response of the charge amplifier is within specification. Test setup is shown in Figure 5-1. The conditions of paragraph 5.2 apply.

The test is designed around the 5% bandpass frequency points of a standard Model 2721B Charge Amplifier. If the low-pass filter frequency-response characteristics are being tested (refer to Table 3-3) switch the filter in and change the high frequency 5% point of this procedure accordingly.

a. Adjust amplifier pC/g sensitivity dial control to 1.00 and mV/g gain control to 1 (or FULL SCALE control to 10K).
b. Adjust signal generator for 100 Hz at 7.07 V rms output.
c. Set switch S1 in test setup to OUT position.
d. Record RMS meter indication.
e. Set signal generator for 3 Hz for 2721B or 2721BM2. If testing 2721BM1 or 2721BM3, set signal generator for 1 Hz.
f. Record RMS meter indication.
g. Set signal generator to 10 kHz.
h. Record RMS meter indication.
i. Verify the recorded values of Steps f and h are within ±5% of the recorded value of Step d.

5.8 NOISE TEST

This test verifies that the noise-level output of the charge amplifier is within specification.

a. Connect equipment as shown in Figure 5-2.

b. Adjust amplifier pC/g sensitivity dial control to 1.00

c. Set amplifier mV/g gain control to 100 (or g FULL SCALE to 100).

d. RMS meter should indicate an output noise level of 17 mV rms or less.

5.9 CALIBRATION

Calibration is required only if it has been determined that the gain or sensitivity of the unit is not within the published specifications (refer to paragraphs 5.5 and 5.6). If the unit requires calibration, proceed as follows:

5.9.1 DISASSEMBLY

CAUTION

Do not attempt to disassemble charge amplifier with power applied.

Access to the calibration points is gained by removing eight (8) Phillips head screws that secure the front and rear panel to the extrusion. The internal components adjusted as part of the calibration procedure are shown in Figure 5-3.

5.9.2 PRELIMINARY PROCEDURE

a. Connect equipment as shown in Figure 5-4.

b. Apply power to amplifier and allow 15 minutes for unit to temperature stabilize.

c. Apply power to remaining equipment used in test setup and allow sufficient time for temperature stabilization.

d. Conditions of paragraph 5.2 apply.

5.9.3 SENSITIVITY CALIBRATION PROCEDURE

a. Set signal generator to 100 Hz

b. Referring to Figure 5-4, set switches S1 and S2 as shown in test setup.

c. Adjust signal generator output to 7.07 V rms.

d. Set switch S2 to OUT position.

e. Adjust amplifier pC/g sensitivity dial control to 10.00 and mV/g switch to 1 (or FULL SCALE control to 10K).

f. Record RMS meter indication.

g. Set switch S1 to B position.

h. Adjust amplifier pC/g sensitivity dial control to 1.00.

i. Adjust sensitivity calibration potentiometer R18 (see Figure 5-3) for an indication on RMS meter that is equal to indication recorded in Step f.

j. Set switch S1 to A position.

k. Repeat Steps e through i until no adjustment of R18 is required for equal readings in Steps f and i.

5.9.4 GAIN CALIBRATION PROCEDURE

a. Referring to Figure 5-4, set witch S1 to A position.

b. Set switch S2 to IN position.

c. Set signal generator to 100 Hz and adjust output for 7.07 V rms indication on RMS meter.

d. Set switch S2 to OUT position.

e. Adjust amplifier pC/g sensitivity dial control to 1.00 and mV/g gain switch to 1 (or FULL SCALE control to 10K).

f. Adjust gain calibration potentiometer R15 (see Figure 5-3) for 7.07 V rms indication on RMS meter.

g. Set switch S2 to IN position.

h. Decrease signal generator output to 70.7 mV rms at 100 Hz.

i. Set switch S2 to OUT position.

j. Set amplifier mV/g gain switch to 100.

k. RMS meter indication should be 7.07 ±0.07 V rms.

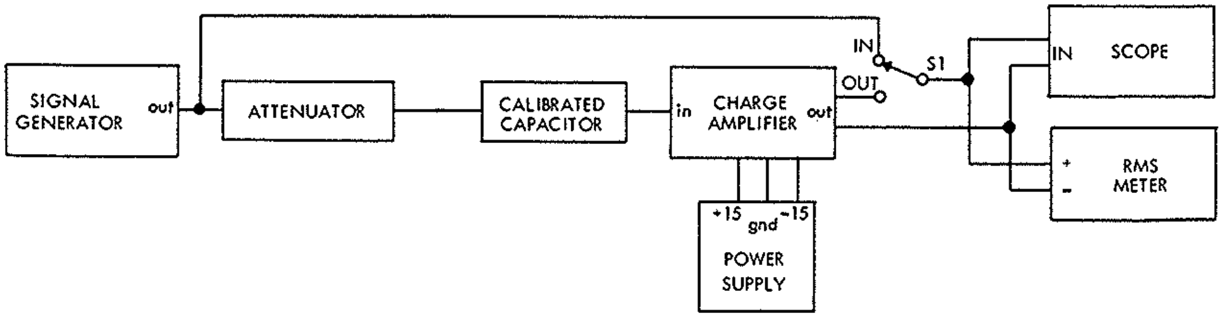

Figure 5-1. Operation Check Set-Up.

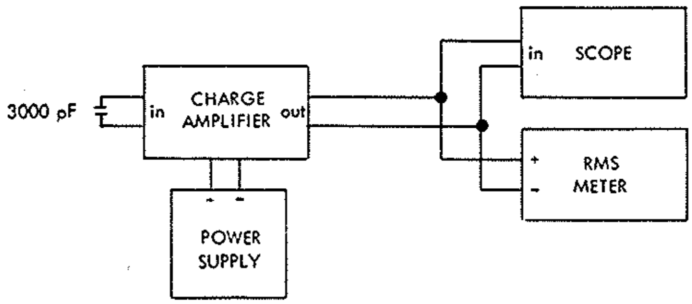

Figure 5-2. Noise Check Set-Up.

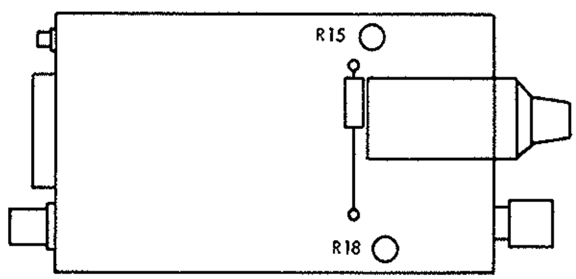

Figure 5-3. Calibration Points.

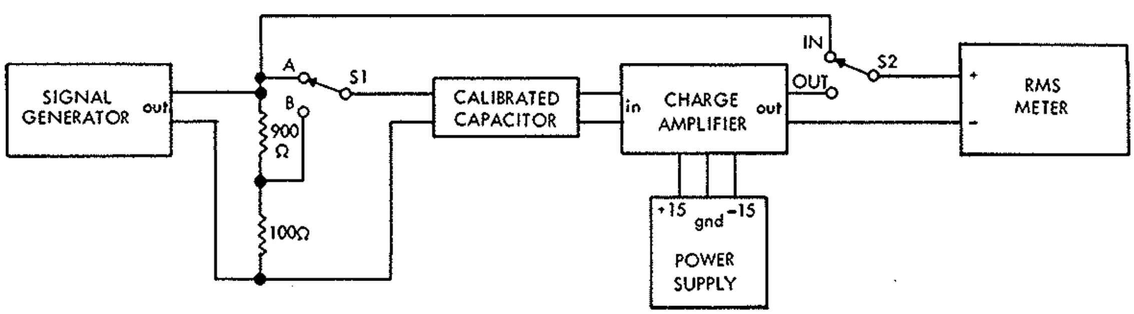

Figure 5-4. Recalibration Set-Up.

5.10 FAULT ISOLATION

Table 5-3 contains a fault isolation chart that can be used to assist in locating troubles in the charge amplifier. The table lists fault symptoms within functions of the unit, and is to be used only as a guide to isolate possible troubles. When isolating a fault, use the appropriate test setup for the function under suspect.

When a fault is isolated to a specific circuit stage, normal troubleshooting procedures should be used to further isolate the fault to a component. Voltage measurements should be used to troubleshoot circuit stages and certain components. Resistance measurements can then be used to locate a faulty component.

The functional block diagram in Figure 4-1 and the applicable charge ammplifier's schematic in Section 7 are to be used when using the fault isolation instructions.

5.11 FACTORY REPAIR

Endevco warrants each new charge amplifier to be free from defects in material and workmanship for one year from date of shipment to the original purchaser. The Warranty document (Form 124-1) contained in Section 7 should be reviewed for complete warranty instructions prior to performing any maintenance service.

If serious problems occur outside the scope of the warranty and the charge amplifier cannot be adjusted or repaired to meet specifications, the unit should be carefully repacked and returned to the factory with all transportation charges prepaid. A statement describing the fault noted and authorization to proceed with repair should accompany the defective charge amplifier.

Address all shipments and correspondence to:

Service Engineering Department
Endevco
Rancho Viejo Road
San Juan Capistrano, CA 92675

TABLE 5-3. FAULT ISOLATION.

Function	Symptom	Probable Cause	Corrective Action
	NOTE: Only black scale is used to reference range switch settings for 2721B and 2721BM1. Black switch settings for 2721BM2 and 2721BM3 are in parenthesis.		
Gain	Amplifier gain OK on 10, 30 and 100 range switch settings (or 1K, 200 and 100) but no gain-of-unity at 1 and 3 settings (10K and 3K).	R13 or S1	Check R13 resistance. Should be 33 830 to 37 170 ohms. Replace R13 if out-of-tolerance. If resistance OK, replace S1.
	Amplifier gain OK on 1, 3 and 100 range switch settings (or 10K, 3K and 100) but no gain-of-10 at 10 and 30 settings (1K and 300).	R12 or S1	Check R12 resistance. Should be 3383 to 3417 ohms. Replace R12 if out-of-tolerance. If resistance OK, replace S1.
	Amplifier gain OK on 1, 3, 10 and 30 range switch settings (or 10K, 3K, 1K and 300), but no gain of 33.3 (or 30.1) at 100 setting.	R11 or S1	Check R11 resistance. Should be 1015 to 1025 (or 1124 to 1136) ohms. Replace R11 if out-of-tolerance. If resistance OK, replace S1.
	Improper gain at all switch settings.	R14 and/or R15, R7, R8 R9, R10, Z2	Check total resistance of R14 + R15. Should be approximately 34.0 k. If not, perform Gain Calibration test in paragraph 5.9.4. If unable to obtain proper test results, check R7-R10, R14 and R15 resistance. Replace defective component. If all resistors good, replace Z2.

TABLE 5-3. FAULT ISOLATION (CONT'D).

Function	Symptom	Probable Cause	Corrective Action
Frequency Response	Low frequency response out-of-specification. Frequency response not flat down to 3 Hz for 2721B and 2721BM2, or 1 Hz for 2721BM1 and 2721BM3. High end OK.	Dirty J1 INPUT connector.	Check connector J1 for foreign particles. Clear with compressed air.
		Q1 or Z1 Operational Amplifier No. 1 and associated components.	Check ouput voltage at Z1 pin 10. Voltage should be approximately -0.5 to -1 V. If OK, check voltage at Q1 pin D. Voltage should be 2-7 V. If voltage is lower than 2-7 V, replace Q1. If voltage is higher that 2-7 V, replace Z1.
	High frequency response out-of-specification. Frequency response not flat up to 10 kHz. Low end OK.	Z2 and associated components.	Check output voltage at Z2 pin 6. Voltage should be approximately -200 mV. If voltage is incorrect, check voltage at Z1 pin 12. Voltage should be approximately +200 mV. If voltage is OK, check components associated with Z2. Replace faulty components. If components OK, replace Z2.
		Z1 Operational Amplifier No. 2 and associated components.	If voltage at Z1 pin 12 is incorrect, check associated components. Replace faulty components. If components OK, replace Z1.

TABLE 5-3. FAULT ISOLATION (CONT'D).

Function	Symptom	Probable Cause	Corrective Action
Noise	Excessive residual noise at low frequency response. Grass at low frequency is high and tails off to normal grass at high frequency. (Note: normal noise should be 17 mV rms or less).	Q1	Replace Q1
	Excessive noise at high frequency response. Grass at low frequency is normal, but increases at high end.	Z2	Replace Z2
	Noise level across amplifier's frequency response appears as a changing dc level.	Z1	Replace Z1
Sensitivity	Sensitivity not linear across band when pC/g sensitivity dial control is checked from position 1 through 10.	Sensitivity potentiometer R7 defective	Replace R7

Section 6
ELECTRICAL PARTS LIST

6.1 GENERAL

This section contains a breakdown of the electrical parts used in the Model 2721B series of Charge Amplifiers. The electrical parts listings are prepared in separate tables for each charge amplifier to assist the user in procurement of parts. Table 6-1 provides codes and addresses of the manufacturers of the parts, and Table 6-2 through 6-5 lists the electrical parts for the Models 2721B, 2721BM1, 2721BM2 and 2721BM3 Charge Amplifiers respectively.

6.2 FEDERAL SUPPLY CODE

Manufacturers of parts are identified by a Federal Supply Code (FSCM) in the parts listing. A cross reference between the FSCM and associated manufacturer is contained in Table 6-1. Those manufacturers without an FSCM are identified with one or two-digit code number.

6.3 ENDEVCO PART NUMBER

All parts listed in Tables 6-2 through 6-5 contain an Endevco part number. Those part numbers with an E prefix, or two-part seven- or eight-digit number (XXX-XXX or XXXX-XXXX), are standard commercial parts. These parts can be procured from the manufacturer noted, or from local distributors of standard parts. Endevco part numbers consisting of five-digit numbers (e.g., 14853) are Endevco manufactured components/parts, or in certain instances, are modified standard parts, and these parts are only available from Endevco.

6.4 PART DESCRIPTION

The part description column contains sufficient details for identifying each part for procurement. Types of capacitors and resistors are identified by the following codes:

a. Capacitors: C = Ceramic, E = Electrolytic, M = Mica, MM = Metalized Myler, MY = Mylar, P = Polycarbonate, T = Tantalum.

b. Resistors: C = Composition, CF = Cermet Film, MF = Metal Film, WW = Wire Wound.

TABLE 6-1. FSCM TO MANUFACTURERS INDEX

Code	Address	Code	Address
01121	Allen Bradley Company 1201 South 2nd Street Milwaukee, WI 53204	72928	Gudeman Division Gulton Industries, Inc. 340 West Huron Street Chicago, Il 60610
02660	Amphenol 2801 South 25th Avenue Broadview, IL 60153	75382	Kulka Electric Corp. 633 South Fulton Avenue Mt. Vernon, NY 10550
06668	Texas Instruments, Inc. P. O. Box 1444 12203 Southwest Freeway North Adams, MA 77001	80294	Bourns, Inc. Instrument Division 6135 Magnolia Riverside, CA 92506
09353	C&K, Inc. 103 Morse Street Watertown, MA 02172	81073	Grayhill, Inc. P. O. Box 373 561 Hillgrove Avenue La Grange, IL 60525
24152	S & EI 18800 Parthenia Street Northridge, CA 91324	81349	Military Specification
56289	Sprague Electric Co. 12870 Panama Street Los Angeles, CA 90066	95411	Endevco 30700 Rancho Viejo Road San Juan Capistrano, CA 92675
72136	Elmenco P. O. Box 7600, Louter Avenue Florence, SC 29501	98182	Harris Equipment Corporation 1450 Lunt Avenue Elk Grove Village, IL 60007
		98278	Malco A Microdot Co. 220 Pasadena Avenue South Pasadena, CA 91030

TABLE 6-2. MODEL 2721B CHARGE AMPLIFIER ELECTRICAL PARTS LIST

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
C1	CAPACITOR, 10 pF, ±5%, 100 V, MM	24152	17UB106J	EC1119
C2	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C3	CAPACITOR, 3000 pF, ±1%, 500 V, M	72136	DM19-302F	EC21
C4	CAPACITOR, 3300 pF, ±10%, 200 V, MY	56289	192P33292	EC163
C5	CAPACITOR, 1 uF, ±20%, 100 V, MM	24152	17U-105	EC1061
C6	CAPACITOR, 0.33 pF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C7	CAPACITOR, 100 uF, -10%/+75%, 25 V, E	56289	30D107G025DD2	EC294
C8	CAPACITOR, 0.33 pF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C9	CAPACITOR, 390 pF, ±5%, 500 V, M	72136	DM15-391J	EC609
C10	CAPACITOR, 200 pF, ±5%, 500 V, M	72136	DM15-201J	EC341
C11	CAPACITOR, 68 pF, ±10%, 500 V, M	72136	DM15-680K	EC1081
C12	CAPACITOR, 3 pF, ±0.5%, 500 V, M	72136	DM15-030D	EC132
C13	CAPACITOR, Customer installed, see paragraph 3.5			
C14	CAPACITOR, 330 uF, -10%/+75%, 10 V, E	56289	503D337G010CG	EC1597
CR1	DIODE, IN914	06668	IN914	0207-0914
CR2	DIODE, IN914	06668	IN914	0207-0914
J1	CONNECTOR, BNC ("T" Option Only)	02660	31-221	EJ15
J1	CONNECTOR, Coax, 10-32	98278	031-0185-0001	EJ10
J2	CONNECTOR, BNC	02660	31-221	EJ15
Q1	TRANSISTOR, FET	95411		14853-2
R1	RESISTOR, 2M, ±1%, 1/4 W, CF	01121	CC2004F	0309-2004
R2	RESISTOR, 100 M, ±5%, 1/4 W, C	01121	CB1075	0305-107
R3	RESISTOR, 6.8 K, ±5%, 1/4 W, C	01121	CB6825	0305-682

TABLE 6-2. MODEL 2721B CHARGE AMPLIFIER ELECTRICAL PARTS LIST (CONT'D)

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
R4	RESISTOR, 6.04 M, ±1%, 1/4 W, CF	01121	CC6044F	0309-6044
R5	RESISTOR, 121 K, ±1%, 1/10 W, MF	81349	RN55C1213F	0309-1213
R6	RESISTOR, 3.01 M, ±1%, 1/4 W, CF	01121	CC3014F	0309-3014
R7	POTENTIOMETER, 20 K	95411		13632-5
R8	RESISTOR, 1.91 K, ±1%, 1/10 W, MF	81349	RN55C1911F	0309-1911
R9	RESISTOR, 6 K, ±0.5%, 1/10 W, MF	81349	RN55C6001D	0310-6001
R10	RESISTOR, 12 K, ±0.5%, 1/10 W, MF	81349	RN55C1202D	0310-1202
R11	RESISTOR, 1.02 K, ±0.5%, 1/10 W, MF	81349	RN55C1021D	0310-1021
R12	RESISTOR, 3.40 K, ±0.5%, 1/10 W, MF	81349	RN55C3401D	0310-3401
R13	RESISTOR, 34.0 K, ±0.5%, 1/10 W, MF	81349	RN55C3402D	0310-3402
R14	RESISTOR, 31.6 K, ±1%, 1/10 W, MF	81349	RN55C3162D	0310-3162
R15	POTENTIOMETER, 5 K, ±20%, 1/2 W	80294	3329H-1-502	ER2348
R16	RESISTOR, 10 Ohm, ±5%, 1/4 W,C	01121	CB1005	0305-100
R17	RESISTOR, 510 Ohm, ±5%, 1/4 W, C	01121	CB5115	0305-511
R18	POTENTIOMETER, 200 Ohm, ±20%, 1/2 W	80294	3329H-1-201	ER2401
R19	RESISTOR, 510 K, ±5%, 1/4 W, C	01121	CB5145	0305-514
S1	SWITCH, Rotary	81073	71ADF30-01-Z-AJN	ES213
S2	SWITCH, SPDT	09353	7101AVB	ES233
TB1	TERMINAL STRIP, 3 Terminal	75382	411-1904-3-S1	EE219
Z1	INTEGRATED CIRCUIT, Dual Comp Amp, Selected	95411		EQ241
Z2	INTEGRATED CIRCUIT, Operational Amp	98182	HA2-2525-5	EQ242

TABLE 6-3. MODEL 2721BM1 CHARGE AMPLIFIER ELECTRICAL PARTS LIST

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
C1	CAPACITOR, 10 pF, ±5%, 100 V, MM	24152	17UB106J	EC1119
C2	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C3	CAPACITOR, 3000 pF, ±1%, 500 V, M	72136	DM19-302F	EC21
C4	CAPACITOR, 3300 pF, ±10%, 200 V, MY	56289	192P33292	EC163
C5	CAPACITOR, 3 pF, ±20%, 100 V, MM	24152	230B-1-B305	EC1522
C6	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C7	CAPACITOR, 300 uF, -10%/+75%, 3 V, E	56289	30D307G003DC2	EC197
C8	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C9	CAPACITOR, 390 pF, ±5%, 500 V, M	72136	DM15-391J	EC609
C10	CAPACITOR, 200 pF, ±5%, 500 V,M	72136	DM15-201J	EC341
C11	CAPACITOR, 68 pF, ±10%, 500 V, M	72136	DM15-680K	EC1081
C12	CAPACITOR, 3 pF, ±0.5%, 500 V, M	72136	DM15-030D	EC132
C13	CAPACITOR, Customer Installed, see paragraph 3.5			
C14	CAPACITOR, 330 uF, -10%/+75%, 10 V, E	56289	503D337G010CG	EC1597
CR1	DIODE, IN914	06668	IN914	0207-0914
CR2	DIODE, IN914	06668	IN914	0207-0914
J1	CONNECTOR, BNC ("T" Option Only)	02660	31-221	EJ15
J1	CONNECTOR, Coax, 10-32	98278	031-0185-0001	EJ10
J2	CONNECTOR, BNC	02660	31-221	EJ15
Q1	TRANSISTOR, FET	95411		14853-2
R1	RESISTOR, 2M, ±1%, 1/4 W, CF	01121	CC2004F	0309-2004
R2	RESISTOR, 300 M, ±5%, 1/4 W, C	01121	CB3075	0305-307
R3	RESISTOR, 6.8 K, ±5%, 1/4 W, C	01121	CB6825	0305-682

TABLE 6-3. MODEL 2721BM1 CHARGE AMPLIFIER ELECTRICAL PARTS LIST (CONT'D)

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
R4	RESISTOR, 6.04 M, ±1%, 1/4 W, CF	01121	CC6044F	0309-6044
R5	RESISTOR, 121 K, ±1%, 1/10 W, MF	81349	RN55C1213F	0309-1213
R6	RESISTOR, 3.01 M, ±1%, 1/4 W, CF	01121	CC3014F	0309-3014
R7	POTENTIOMETER, 20 K	95411		13632-5
R8	RESISTOR, 1.91 K, ±1%, 1/10 W, MF	81349	RN55C1911F	0309-1911
R9	RESISTOR, 6 K, ±0.5%, 1/10 W, MF	81349	RN55C6001D	0310-6001
R10	RESISTOR, 12 K, ±0.5%, 1/10 W, MF	81349	RN55C1202D	0310-1202
R11	RESISTOR, 1.02 K, ±0.5%, 1/10 W, MF	81349	RN55C1021D	0310-1021
R12	RESISTOR, 3.40 K, ±0.5%, 1/10 W, MF	81349	RN55C3401D	0310-3401
R13	RESISTOR, 34.0 K, ±0.5%, 1/10 W, MF	81349	RN55C3402D	0310-3402
R14	RESISTOR, 31.6 K, ±1%, 1/10 W, MF	81349	RN55C3162D	0310-3162
R15	POTENTIOMETER, 5 K, ±20%, 1/2 W	80294	3329H-1-502	ER2348
R16	RESISTOR, 10 Ohm, ±5%, 1/4 W, C	01121	CB1005	0305-100
R17	RESISTOR, 510 Ohm, ±5%, 1/4 W, C	01121	CB5115	0305-511
R18	POTENTIOMETER, 200 Ohm, ±20%, 1/2 W	80294	3329H-1-201	ER2401
R19	RESISTOR, 510 K, ±5%, 1/4 W, C	01121	CB5145	0305-514
S1	SWITCH, Rotary	81073	71ADF30-01-Z-AJN	ES213
S2	SWITCH, SPDT	09353	7101AVB	ES233
TB1	TERMINAL STRIP, 3 Terminal	75382	411-1904-3-S1	EE219
Z1	INTEGRATED CIRCUIT, Dual Comp Amp, Selected	95411		EQ241
Z2	INTEGRATED CIRCUIT, Operational Amp	98182	HA2-2525-5	EQ242

TABLE 6-4. MODEL 2721BM2 CHARGE AMPLIFIER ELECTRICAL PARTS LIST

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
C1	CAPACITOR, 10 uF, ±5%, 100 V, MM	24152	17UB106J	EC1119
C2	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C3	CAPACITOR, 3000 pF, ±1%, 500 V, M	72136	DM19-302F	EC21
C4	CAPACITOR, 3300 pF, ±10%, 200 V, MY	56289	192P33292	EC163
C5	CAPACITOR, 1 uF, ±20%, 100 V, MM	24152	17U-105	EC1061
C6	CAPACITOR, 0.33 pF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C7	CAPACITOR, 100 uF, -10%/+75%, 25 V, E	56289	30D107G025DD2	EC294
C8	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C9	CAPACITOR, 390 pF, ±5%, 500 V, M	72136	DM15-391J	EC609
C10	CAPACITOR, 180 pF, ±5%, 500 V, M	72136	DM15-181J	EC999
C11	CAPACITOR, 68 pF, ±10%, 500 V, M	72136	DM15-680K	EC1081
C12	CAPACITOR, 3 pF, ±0.5%, 500 V, M	72136	DM15-030D	EC132
C13	CAPACITOR, Customer installed, see paragraph 3.5			
C14	CAPACITOR, 330 uF. -10%/+75%, 10 V, E	56289	503D337G010CG	EC1597
CR1	DIODE, IN914	06668	IN914	0207-0914
CR2	DIODE, IN914	06668	IN914	0207-0914
J1	CONNECTOR, BNC ("T" Option Only)	02660	31-221	EJ15
J1	CONNECTOR, Coax, 10-32	98278	031-0185-0001	EJ10
J2	CONNECTOR, BNC	02660	31-221	EJ15
Q1	TRANSISTOR, FET	95411		14853-2
R1	RESISTOR, 2M, ±1%, 1/4 W, CF	01121	CC2004F	0309-2004
R2	RESISTOR, 100 M, ±5%, 1/4 W, C	01121	CB1075	0305-107
R3	RESISTOR, 6.8 K, ±5%, 1/4 W, C	01121	CB6825	0305-682

TABLE 6-4. MODEL 2721BM2 CHARGE AMPLIFIER ELECTRICAL PARTS LIST (CONT'D)

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
R4	RESISTOR, 6.04 M, ±1%, 1/4 W, CF	01121	CC6044F	0309-6044
R5	RESISTOR, 121 K, ±1%, 1/10 W, MF	81349	RN55C1213F	0309-1213
R6	RESISTOR, 3.01 M, ±1%, 1/4 W, CF	01121	CC3014F	0309-3014
R7	POTENTIOMETER, 20 K	95411		13632-5
R8	RESISTOR, 1.91 K, ±1%, 1/10 W, MF	81349	RN55C1911F	0309-1911
R9	RESISTOR, 6 K, ±0.5%, 1/10 W, MF	81349	RN55C6001D	0310-6001
R10	RESISTOR, 14 K, ±0.5%, 1/10 W, MF	81349	RN55C1402D	0310-1402
R11	RESISTOR, 1.13 K, ±0.5%, 1/10 W, MF	81349	RN55C1131D	0310-1131
R12	RESISTOR, 3.40 K, ±0.5%, 1/10 W, MF	81349	RN55C3401D	0310-3401
R13	RESISTOR, 34.0 K, ±0.5%, 1/10 W, MF	81349	RN55C3402D	0310-3402
R14	RESISTOR, 31.6 K, ±1%, 1/10 W, MF	81349	RN55C3162D	0310-3162
R15	POTENTIOMETER, 5 K, ±20%, 1/2 W	80294	3329H-1-502	ER2348
R16	RESISTOR, 10 Ohm, ±5%, 1/4 W, C	01121	CB1005	0305-100
R17	RESISTOR, 510 Ohm, ±5%, 1/4 W, C	01121	CB5115	0305-511
R18	POTENTIOMETER, 200 Ohm, ±20%, 1/2 W	80294	3329H-1-201	ER2401
R19	RESISTOR, 510 K, ±5%, 1/4 W, C	01121	CB5145	0305-514
S1	SWITCH, Rotary	81073	71ADF30-01-Z-AJN	ES213
S2	SWITCH, SPDT	09353	7101AVB	ES233
TB1	TERMINAL STRIP, 3 Terminal	75382	411-1904-3-S1	EE219
Z1	INTEGRATED CIRCUIT, Dual Comp Amp, Selected	95411		EQ241
Z2	INTEGRATED CIRCUIT, Operational Amp	98182	HA2-2525-5	EQ242

TABLE 6-5. MODEL 2721BM3 CHARGE AMPLIFIER ELECTRICAL PARTS LIST

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
C1	CAPACITOR, 10 uF, ±5%, 100 V, MM	24152	17UB106J	EC1119
C2	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C3	CAPACITOR, 3000 pF, ±1%, 500 V, M	72136	DM19-302F	EC21
C4	CAPACITOR, 3300 pF, ±10%, 200 V, MY	56289	192P33292	EC163
C5	CAPACITOR, 3 uF, ±20%, 100 V, MM	24152	230B-1-B305	EC1522
C6	CAPACITOR, 0.33 uF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C7	CAPACITOR, 100 uF, -10%/+75%, 3 V, E	56289	30D307G003DC2	EC197
C8	CAPACITOR, 0.33 pF, ±10%, 80 V, MY	72928	356AZ334K	EC1424
C9	CAPACITOR, 390 pF, ±5%, 500 V, M	72136	DM15-391J	EC609
C10	CAPACITOR, 180 pF, ±5%, 500 V, M	72136	DM15-181J	EC999
C11	CAPACITOR, 68 pF, ±10%, 500 V, M	72136	DM15-680K	EC1081
C12	CAPACITOR, 3 pF, ±0.5%, 500 V, M	72136	DM15-030D	EC132
C13	CAPACITOR, Customer installed, see paragraph 3.5			
C14	CAPACITOR, 330 uF, -10%/+75%, 10 V, E	56289	503D337G010CG	EC1597
CR1	DIODE, IN914	06668	IN914	0207-0914
CR2	DIODE, IN914	06668	IN914	0207-0914
J1	CONNECTOR, BNC ("T" Option Only)	02660	31-221	EJ15
J1	CONNECTOR, Coax, 10-32	98278	031-0185-0001	EJ10
J2	CONNECTOR, BNC	02660	31-221	EJ15
Q1	TRANSISTOR, FET	95411		14853-2
R1	RESISTOR, 2 M, ±1%, 1/4 W, CF	01121	CC2004F	0309-2004
R2	RESISTOR, 300 M, ±5%, 1/4 W, C	01121	CB3075	0305-307
R3	RESISTOR, 6.8 K, ±5%, 1/4 W, C	01121	CB6825	0305-682

TABLE 6-5. MODEL 2721BM3 CHARGE AMPLIFIER ELECTRICAL PARTS LIST (CONT'D)

Ref Des	Part Description	FSCM	Manufacturer's Part No.	Endevco Part No.
R4	RESISTOR, 6.04 M, ±1%, 1/4 W, CF	01121	CC6044F	0309-6044
R5	RESISTOR, 121 K, ±1%, 1/10 W, MF	81349	RN55C1213F	0309-1213
R6	RESISTOR, 3.01 M, ±1%, 1/4 W, CF	01121	CC3014F	0309-3014
R7	POTENTIOMETER, 20 K	95411		13632-5
R8	RESISTOR, 1.91 K, ±1%, 1/10 W, MF	81349	RN55C1911F	0309-1911
R9	RESISTOR, 6 K, ±0.5%, 1/10 W, MF	81349	RN55C6001D	0310-6001
R10	RESISTOR, 14 K, ±0.5%, 1/10 W, MF	81349	RN55C1402D	0310-1402
R11	RESISTOR, 1.13 K, ±0.5%, 1/10 W, MF	81349	RN55C1131D	0310-1131
R12	RESISTOR, 3.40 K, ±0.5%, 1/10 W, MF	81349	RN55C3401D	0310-3401
R13	RESISTOR, 34.0 K, ±0.5%, 1/10 W, MF	81349	RN55C3402D	0310-3402
R14	RESISTOR, 31.6 K, ±1%, 1/10 W, MF	81349	RN55C3162D	0310-3162
R15	POTENTIOMETER, 5 K, ±20%, 1/2 W	80294	3329H-1-502	ER2348
R16	RESISTOR, 10 Ohm, ±5%, 1/4 W, C	01121	CB1005	0305-100
R17	RESISTOR, 510 Ohm, ±5%, 1/4 W, C	01121	CB5115	0305-511
R18	POTENTIOMETER, 200 Ohm, ±20%, 1/2 W	80294	3329H-1-201	ER2401
R19	RESISTOR, 510 K, ±5%, 1/4 W, C	01121	CB5145	0305-514
S1	SWITCH, Rotary	81073	71ADF30-01-Z-AJN	ES213
S2	SWITCH, SPDT	09353	7101AVB	ES233
TB1	TERMINAL STRIP, 3 Terminal	75382	411-1904-3-S1	EE219
Z1	INTEGRATED CIRCUIT, Dual Comp Amp, Selected	95411		EQ241
Z2	INTEGRATED CIRCUIT, Operational Amp	98182	HA2-2525-5	EQ242

Section 7

DRAWINGS AND SUPPORTING DOCUMENTS

The following drawing and supporting documents form a part of the Model 2721B Series Instruction Manual.

a. Drawing C-2721B-1C — 2721B Charge Amplifier Main Assembly

b. Drawing C-2721B-501C — 2721B Change Amplifier Schematic

c. Drawing C-2721BM1-1C — 2721BM1 Charge Amplifer Main Assembly

d. Drawing C-2721BM1-501C — 2721BM1 Charge Amplifier Schematic

e. Drawing C-2721BM2-1C — 2721BM2 Charge Amplifier Main Assembly

f. Drawing C-2721BM2-501C — 2721BM2 Charge Amplifier Schematic

g. Drawing C-2721BM3-1C — 2721BM3 Charge Amplifier Main Assembly

h. Drawing C-2721BM3-501C — 2721BM3 Charge Amplifier Schematic

i. Drawing C-23732C — 2721B Series Circuit-Board Assembly

j. Endevco Signal Conditioner and Power Supply Requirements Chart

k. Model 2721B Series Product Data Sheet

l. Warranty, Form 124-1

m. Endevco Field Offices

ENDEVCO® SIGNAL CONDITIONERS AND POWER SUPPLY REQUIREMENTS

SIGNAL CONDITIONER										
Model	Input Voltage (V DC)	Current (mA)	Size (See Note 1)		Maximum Signal Conditioners Per Power Supply					
			H x W x L (Inches)	H x W x L (Millimeters)	4221	4221A	4222	4223	4224	4225
2721	±14 to ±18	9.5	3.00 x 1.75 x 5.125	65.2 x 44.5 x 130.18	4	10	8	3	2	N/A
2721A Series	±14 to ±18	9.5	3.00 x 1.75 x 5.125	65.2 x 44.5 x 130.18	4	10	8	3	2	N/A
2721B Series	±14 to ±18	9.5	3.00 x 1.75 x 5.125	65.2 x 44.5 x 130.18	4	10	8	3	2	N/A
4422	±15	[illegible] Plus Transducer	[illegible]	65.2 x 44.5 x 130.18	0	2	[illegible]	[illegible]	[illegible]	N/A
4423	[illegible] to ±35	[illegible] Plus Transducer	[illegible]	65.2 x 44.5 x 130.18	N/A	N/A	N/A	N/A	N/A	[illegible]
NOTE 1: H x W x L = Height x Width x Length. Length is without dials and connectors.										

POWER SUPPLY					
Model	Source Voltage	Output Voltage (V DC)	Output Current (mA)	Size (See Note 1)	
				H x W x L (Inches)	H x W x L (Millimeters)
4221	100-130 V ac 50-60 Hz or 200-260 V ac 50-60 Hz Switch Selectable	±15	40	3.00 x 1.75 x 5.125	76.2 x 44.5 x 130.18
4221A	Standard: 105-125 V ac V-Option: 200-252 V ac W-Option: 90-100 V ac All 50-400 Hz	±15	100	3.00 x 1.75 x 5.125	76.2 x 44.5 x 130.18
4222	100-130 V ac 50-60 Hz or 200-260 V ac 50-60 Hz Switch Selectable	±15	80	3.00 x 3.00 x 5.125	76.2 x 76.2 x 130.18
4223	Four Disposable 9 V Alkaline Batteries	±18	30	3.00 x 1.00 x 5.125	76.2 x 25.4 x 130.18
4224	Four Rechargeable 7.5 V Nickel-Cadmium Batteries Use Charger 2904	±12 to ±17	20	3.00 x 1.75 x 5.125	76.2 x 44.5 x 130.18
4225	Standard: 105-125 V ac V-Option: 200-252 V ac W-Option: 90-100 V ac All 50-400 Hz	±18 to ±35 Unregulated	400	3.00 x 3.00 x 5.125	76.2 x 76.2 x 130.18
NOTE 1: H x W x L = Height x Width x Length. Length is without dials and connectors.					

MODEL 4914A RACK ADAPTER CAPACITY OF SIGNAL CONDITIONERS AND POWER SUPPLY(S) COMBINATION						
Signal Conditioner	Power Supply					
	4221	4221A	4222	4223	4224	4225
2721	8 + 2	9 + 1	8 + 1	8 + 3	6 + 3	N/A
2721A	8 + 2	9 + 1	8 + 1	8 + 3	6 + 3	N/A
2721B	8 + 2	9 + 1	8 + 1	8 + 3	6 + 3	N/A
4422	0	6 + 3	3 + 3	0	0	N/A
4423	N/A	N/A	N/A	N/A	N/A	6 + 2

NOTES:
1) Number preceding + sign is quantity of signal conditoners. Number following + sign is quantity of power supplies.
2) 4914 Inside dimension is 17.00 inches (adjust quantities accordingly).
3) 4914A Inside dimension is 17.50 inches.
4) Some combinations do not completely fill the rack adapter.