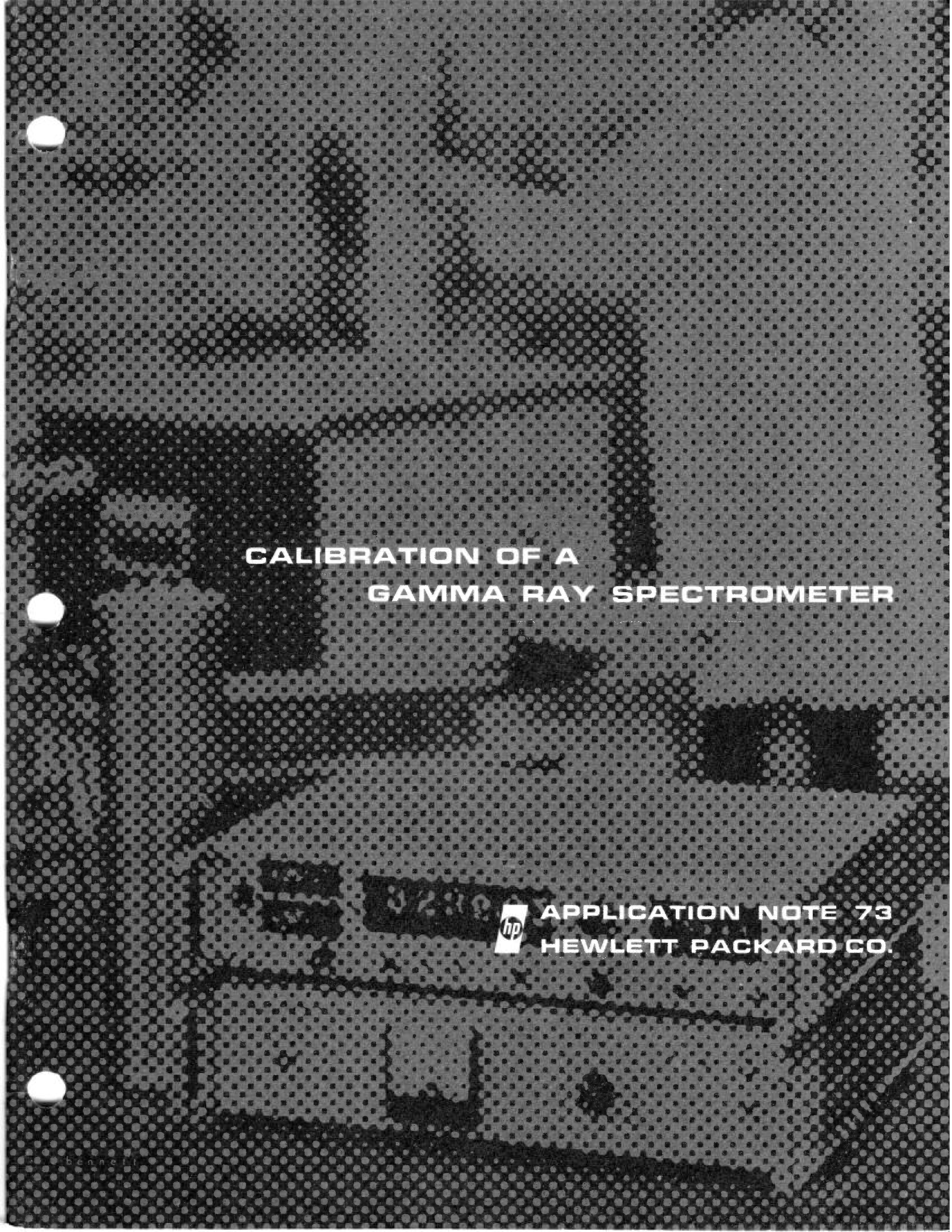
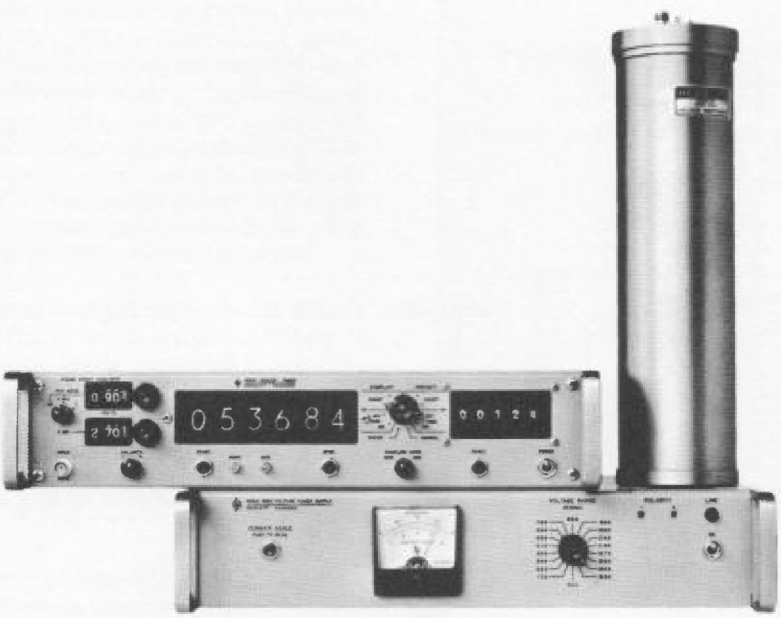


CALIBRATION OF A GAMMA RAY SPECTROMETER

APPLICATION NOTE 73
HEWLETT PACKARD CO.

CALIBRATION OF A GAMMA RAY SPECTROMETER



FREQUENCY AND TIME DIVISION, PALO ALTO, CALIFORNIA, U.S.A.

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CALIBRATION OF A GAMMA RAY SPECTROMETER

INTRODUCTION

A Hewlett-Packard 5201L Scaler-Timer, a 5551A High Voltage Power Supply, and any one of the Series 10600A Scintillation Detectors constitute a gamma ray spectrometer. This application note presents step-by-step procedures for the calibration of this single-channel spectrometer to the range of gamma ray energy the user selects. While the details relate specifically to the spectrometer discussed, the basic relationships and the manner in which the calibrations are made apply also to systems based upon ratemeters. The general approach is that of differential counting.

Gamma ray spectrometry has grown from small beginnings around 1950 until today large catalogs of gamma ray spectra cover most isotopes of importance to areas such as nuclear reactor operation and nuclear physics research. Uses for gamma ray spectra include identification of unknown isotopes and quantitative measurement by comparison of photopeak counts in the unknown and in a calibrated sample of the same isotope.

The scintillation detector's high efficiency for gamma rays makes it suitable for measurements on low activity gamma-emitting sources. This capability leads to numerous applications in areas such as radiochemistry, clinical medicine (diagnostic work with tracers), biomedical research, geology, meteorology, and metallurgy.

Figure 1 shows a gamma ray spectrum for cesium-137 obtained with a Hewlett-Packard scintillation spectrometer. The prominent photopeak corresponds to the 662 keV gamma ray which characterizes this isotope. Cs-137, which is readily available and has a relatively simple spectrum, is often used to calibrate gamma ray spectrometers.

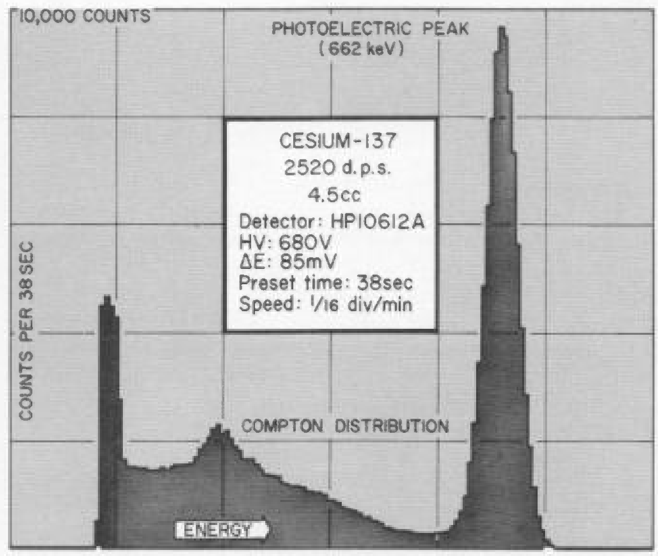


Figure 1. Gamma spectrum for cesium-137

A concise description of the functions essential to a gamma ray spectrometer follows next for use by those readers who may wish to review these functions from the standpoint of the Hewlett-Packard system, before reading the detailed calibration procedures. These procedures are followed by a check list which is a summary that includes only those details the experienced user will want for reference. An appendix gives instrument details: front and rear panel views and operating instructions.

GAMMA RAY SPECTROMETER

Two of the essential functions of a gamma ray spectrometer, to detect gamma rays and to measure their energies, are performed in the scintillation detector and in the pulse height analyzer.

SCINTILLATION DETECTOR

The scintillation detector has three parts: (1) the scintillation phosphor crystal (usually thallium activated sodium iodide), (2) the photomultiplier tube, and (3) the amplifier. Figure 2 shows a block diagram. Gamma rays from the gamma emitter to be measured enter the detector and traverse the scintillation crystal, giving up their energy in exciting and ionizing its atoms. These excited atoms then radiate energy as flashes of light. Each group of flashes (scintillations) is nearly proportional to the energy of the incident gamma ray absorbed in the crystal. The light passes through the transparent crystal and some of it is received at the photocathode, where it ejects electrons. In the photomultiplier tube, these electrons are accelerated to the first of a series of dynodes. The electrons which strike each dynode produce many more electrons by secondary emission, a progressive effect which builds into a multiplication factor of about 10^5, yet maintains proportionality. The photomultiplier anode collects the resulting burst of charge, which is delivered through the output capacitor to the amplifier input. The charge is integrated and amplified to produce a voltage step, then it is differentiated (clipped) to produce a pulse of optimum shape for input to the pulse height analyzer. Throughout the entire process, the proportionality to the energy of the incident gamma ray is closely maintained. Thus, a single gamma ray's energy is transformed into a single voltage pulse suitable for measurement.

PHOTOMULTIPLIER TUBE HIGH VOLTAGE SETTING

A change in the voltage provided by the high voltage supply to the photomultiplier tube changes the output signal amplitude; an increase in voltage to the photomultiplier's dynodes causes an increase in the amplitude of the output pulse for a given gamma ray energy. This effect is used to adjust the system for measurements of gamma rays within a selected energy range. That is, by selection of the high voltage setting, pulse amplitudes within the range acceptable to the system can be made to correspond to gamma ray energies in, say, the range of thousands of electron volts* (keV) or of millions of electron volts (MeV).

AMPLIFIER

It is necessary to convert the output current pulses from the photomultiplier into voltage pulses and to amplify and shape these pulses so that they are suitable for triggering the scaler-timer circuits. The Hewlett-Packard detector uses a charge-sensitive preamplifier with a conversion gain of approximately 25 picocoulombs per volt. The subsequent amplifiers have a voltage gain of 10 or 100. The gain of these amplifiers and that of the photomultiplier must be considered in the calibration of the spectrometer.

*Note: The electron volt is an energy unit, the energy gained by an electron in passing through a potential difference of one volt: $1\ eV = 1.6 \times 10^{-12}$ erg, keV = kilo-electron volt, MeV = million-electron volt.

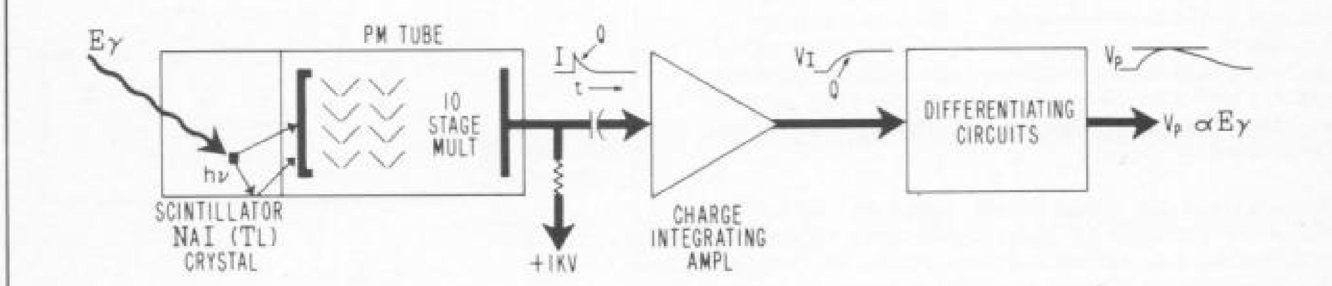


Figure 2. Scintillation detector block diagram

PULSE HEIGHT ANALYZER

The single-channel pulse height analyzer sorts the pulses from the scintillation detector according to amplitude, passing those lying between two preselected limits to the scaler-timer and discriminating against others.

Each input pulse is presented to a pair of discriminators, referred to as the lower level discriminator and the upper level discriminator; E_{min} and E_{max} are the energies to which the trigger levels of these discriminators correspond. These two limits define a "window" or "channel" corresponding to an energy band of width ΔE. To understand the action of these discriminators, consider three cases where: (1) the pulse height is less than the preset value of E_{min}, (2) the pulse height is greater than E_{min} but less than E_{max}, and (3) the pulse is greater than both. Figure 3 diagrams these pulses and shows their relationship to a typical spectrum.

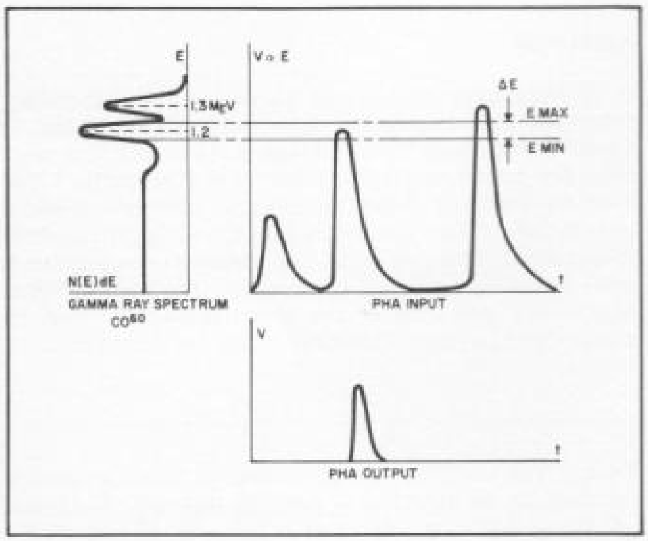


Figure 3. Differential pulse height discrimination

In the first case, the pulse is not propagated farther since it is not large enough to trigger the lower level discriminator. In the second case, the pulse falls within the ΔE window; this pulse is propagated and passed to the scaler. In the third case, the pulse triggers both discriminators. This large pulse is propagated to an anticoincidence circuit so designed that when pulses are received from both discriminators in time coincidence, both are blocked and no output pulse is passed to the scaler. Figure 4 shows the signal input.

The action of the pulse height analyzer, then, has been to discriminate against pulses larger or smaller (differential discrimination) than pulses of the predetermined size. These selected pulses are transmitted to the scaler for totalization.

SCALER-TIMER

The scaler-timer accumulates and stores pulses in digital form. The scaler can totalize the pulses during a precisely defined time period. Since scaler-timer input can reach hundreds of thousands of pulses each minute, the scaler must be capable of high speed counting. Operation can be set for predetermined count or for predetermined time.

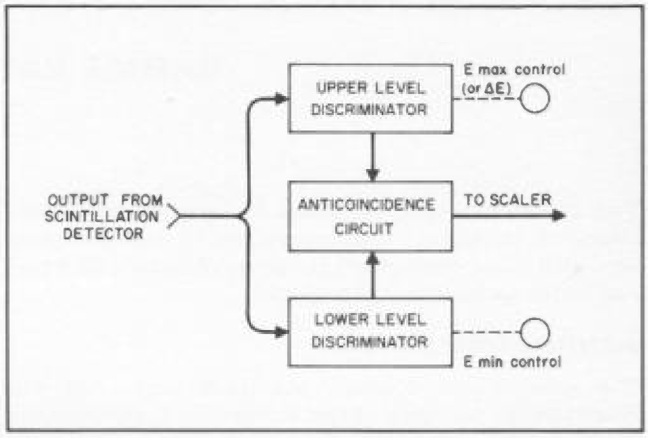


Figure 4. Pulse height analyzer block diagram

To enter the scaler's first decimal counter assembly (DCA), the signal from the pulse height analyzer must pass the decimal counter assembly gate. This DCA gate may be enabled or disabled by either manual control (front panel pushbuttons), built-in timer control, or external control (another scaler, external timer, or other device). Figure 5 shows a block diagram of a Hewlett-Packard scaler. Each decimal counter assembly consists of four binary "flip-flops" (bistable multivibrator circuits) arranged in such a way that the DCA will put out one pulse for every ten pulses received. When the tenth pulse is received, the DCA (Decade) is reset to zero, and a pulse is sent to the next decade. This process is repeated down the line of decimal counting assemblies so that the record of the number of pulses received is stored by the decades. When the pulses to the decades are blocked (by disabling the DCA gate), the counting stops and the number of pulses accumulated is read out by a decoding arrangement into a visual numerical form (digital display tubes).

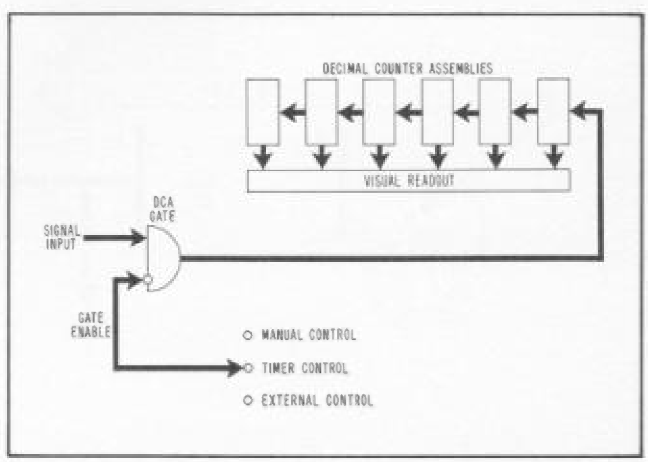


Figure 5. Scaler block diagram

GAMMA RAY SPECTROMETRY

A gamma ray spectrometer operating to perform pulse height analysis in the manner just described can give the data needed for plotting a gamma spectrum. With a single channel analyzer, a series of measurements are made on the isotope of interest by having the spectrometer totalize the count for a range of pulse heights corresponding to a narrow energy band; this count is repeated in turn for successive energy bands. Then, a plot of count rate vs pulse height (energy) constitutes the isotope's gamma ray spectrum.

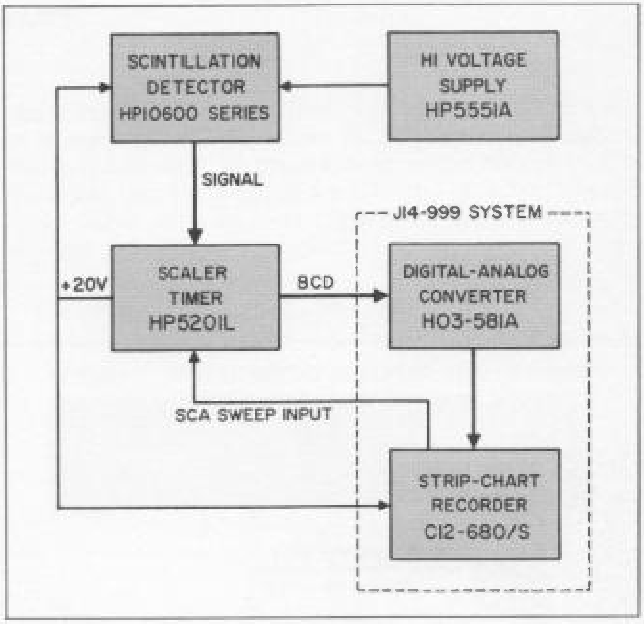


Figure 6. Scanning spectrometer block diagram

To more conveniently and automatically obtain the data for a spectrum, a system which scans the energy range and records the data can be arranged as shown in Figure 6. In this HP system, the sweep input determines the value of E_{min}. The ΔE window formed by the E_{min} and E_{max} discriminators is moved through the complete voltage range by the sweep input to scan the spectrum automatically.

CALIBRATION

Gamma ray spectrometer calibration is basically a matter of establishing a known relationship between gamma ray energy (keV or MeV) and the discriminator scales (scale divisions or volts) so that pulse heights can be translated to energies.

The calibration procedure for the Hewlett-Packard 5201L Scaler-Timer, the 5551A High Voltage Supply, and one of the Scintillation Detectors, Series 10600A, will be set forth in detail.

For the convenience of those readers who are not completely familiar with the controls and operation of the HP instruments, the appendix presents information reproduced from their operating and service manuals. Front and rear panel views show all controls and terminals referred to in the calibration procedure, and charts outline basic instrument turn-on and operation.

GENERAL

The calibration factor for the HP 5201L can be expressed in terms of electron volts (keV or MeV) per volt or per scale division. To establish it, a sample having known gamma ray energy is measured.

Cesium 137, often used for this purpose, has a distinct photopeak at 662 keV and also a sharp peak at 31.5 keV (due to the barium-137 x-ray). A 0.5 microcurie Cs-137 source* was used throughout the calibration measurements to be described.

Calibration of the HP 5201L is made easy and quick by the automatic recycling mode and the storage display features exclusive with the HP Scaler-Timers. When a short preset time is selected, say 1 sec, then the measurement for that period is held and displayed during the next counting period. This display makes it easy for the user to observe the count rate while he is adjusting other controls accordingly.

First to be discussed is the determination of the calibration factor related to a given high voltage setting, and next, the procedure to set the voltage range of the discriminators (0 to 5 volts) to cover a selected gamma ray energy range (say, 0 to 1 MeV; calibration factor, 0.2 MeV per volt). Finally, a graphical method to estimate the high voltage setting appropriate to a given energy range is described. The user may select from these methods the particular calibration best suited to his purpose.

EQUIPMENT ARRANGEMENT

Figure 7 is a block diagram indicating the connection of the 5201L, the 5551A, and the 10613A. Any one of the Series 10600A scintillation detectors could be used. A source giving 10,000 to 20,000 counts per second (integral counts) is placed next to the detector or is inserted into the well, if a well-type detector is used. This same arrangement applies for each of the calibration procedures to follow.

*Well-type lucite-enclosed source made by Hazleton Nuclear Science Corporation.

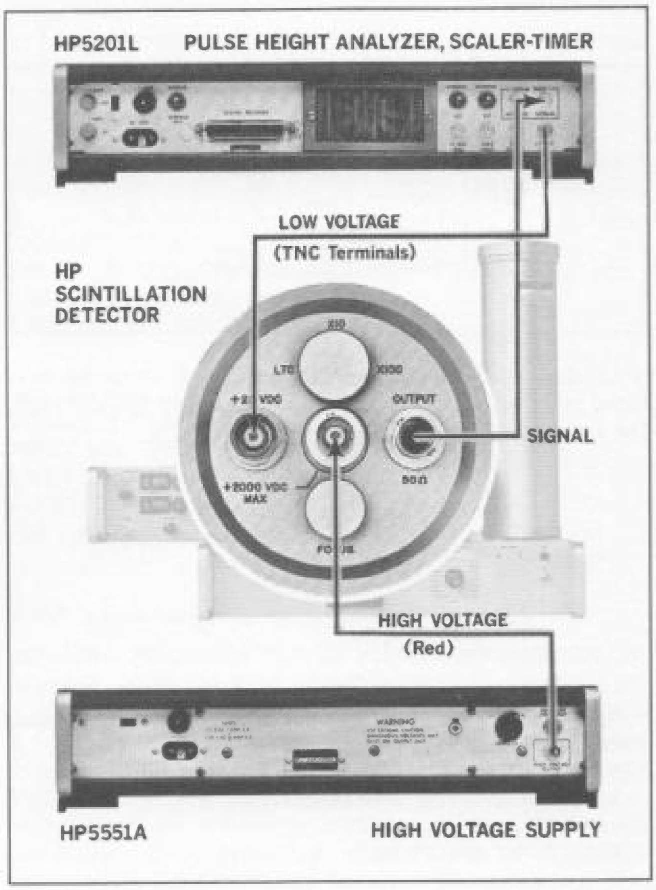


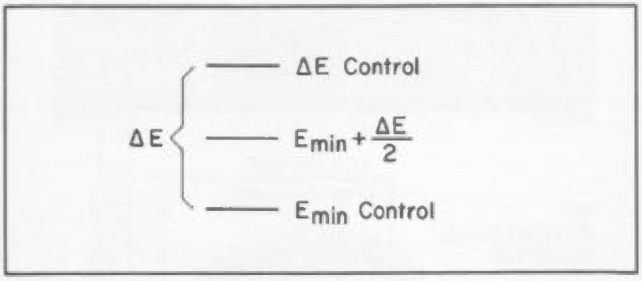
Figure 7. Block diagram, HP system for gamma ray spectrometry (single channel analyzer)

DETERMINATION OF THE CALIBRATION FACTOR FOR A GIVEN HIGH VOLTAGE SETTING

It is convenient to know the calibration factor (keV or MeV per volt) relative to one of the 85-volt steps which may be selected by use of the VOLTAGE RANGE SELECTOR on the front panel of the 5551A High Voltage Power Supply because the user can quickly and accurately reset to this same point, once it has been established.

The equipment arrangement is that shown in Figure 7. The procedure to be followed is simple. First, with the 5201L in integral mode, the gain is adjusted to bring the 662 keV photopeak of Cs-137 (or a selected peak of known standard) within range of the discriminators. Next, with the 5201L in ΔE (narrow-window) mode, the operator locates the energy peak accurately by advancing E_{min} (the lower level discriminator) until the count rate is a maximum. A quick computation then gives the calibration factor.

When the 5201L's pulse height analyzer is operated in the ΔE mode, the upper level discriminator control sets and holds constant the desired window width (ΔE), the lower level discriminator sets E_{min}, and ΔE is referenced to E_{min}. At the selected value of E_{min}, all pulses with heights between E_{min} and $E_{min} + \Delta E$ will be passed to the scaler-timer and totalized. The mid-window reference is exactly given by $E_{min} + \frac{\Delta E}{2}$:



It is this mid-window reference which is to be related precisely to an energy peak in order to calibrate the spectrometer.

Procedure

1. Set controls as follows (refer to the Appendix for details):

5201L	Rear Panel
AC POWER: On	STORAGE: Normal
PHA MODE: ∫ (Integral)	E_{min} BIAS: Normal
E_{min}: 4.5 volts	GATE: Normal

POLARITY: +
DISPLAY-PRESET:
Display Count - Preset Time, sec
SAMPLING MODE: Auto
PRESET "N" SWITCHES: 1.0 (sec)

5551A

POLARITY (Rear Panel): +
VOLTAGE RANGE: 680 volts
VERNIER: Fully counterclockwise
AC POWER: On

Note: settings for VOLTAGE RANGE and E_{min} are examples, not fixed values applicable in all cases.

10613A

GAIN: X10 (or X100 as desired)

Note: the calibration is valid only for the gain (X10 or X100) used during calibration.

2. Increase the high voltage in 85-volt steps by clockwise resets of the VOLTAGE RANGE control. (Keep the VERNIER control switched out by turning it fully counterclockwise; it is not used in this procedure.) At each new voltage setting, observe the count. Note the setting where there is a sudden increase in the number of counts. For example, the observations might be as follows:

High Voltage	Counts per sec
765 (volts)	1
850	1
935	1
1020	2
1105	11
1190	1700

The actual count depends upon a number of factors including source strength and geometry. The significant observation is the large jump in count rate rather than count value. The operator now knows that at E_{min} = 4.5 volts and with the VOLTAGE RANGE selector set at 1105 volts, the 662 keV energy peak is within range. It remains to measure this peak and to determine the calibration factor.

3. Leaving the VOLTAGE RANGE set at 1105 volts, change PHA MODE to ΔE = 0.100 volt and change the preset "N" switches to 5.0 (sec). A longer count is needed since use of the narrow window mode will reduce the count rate. Reset E_{min} to a level somewhat below 4.50 volts and observe the count as it is progressively raised in 0.10 volt steps, for example:

E_{min}	Counts per 5 sec
4.10	908
4.20	1512
4.30	1771
4.40	1255
4.50	635
4.60	194

The maximum count is observed to be at E_{min} = 4.30 volts.

Note

During any count accumulation period when either the high voltage setting or one of the discriminators is changed, the count displayed is apt to be in error. After making any change, therefore, press the RESET button.

4. Compute the Calibration Factor, MeV/volt:

$$\text{C. F., MeV/volt} = \frac{\text{Energy Peak, MeV}}{E_{min}\text{, volts} + \frac{\Delta E}{2}\text{, volts}}$$

$$= \frac{0.662}{4.30 + \frac{0.10}{2}} = \frac{0.662}{4.35}$$

$$= 0.15\ \text{MeV/volt}$$

5. Find the 0-5 volt calibration range:

$$5\ \text{volts} \times 0.15\ \frac{\text{MeV}}{\text{volt}} = 0.750\ \text{MeV}$$

Range: 0 to 750 keV.

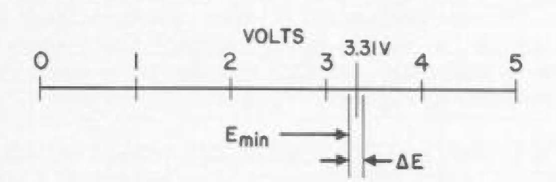
The gamma ray spectrometer is now calibrated. Provided that the VOLTAGE RANGE control is reset to the same value (and the scintillation detector's GAIN switch is set as it was during the calibration), $E_{min} + \Delta E/2$ readings are now related precisely to gamma ray energies.

If a more accurate calibration is desired, the operator can improve counting statistics by taking a longer count at each E_{min} setting and by interpolating between settings (the peak is known to be symmetrical at its top). When this longer procedure was followed for the example just presented, it was found that $E_{min} = 4.275$ volts rather than 4.30 volts.

CALIBRATION TO A SELECTED RANGE OF GAMMA RAY ENERGY

A useful and convenient gamma ray spectrometer calibration is to have the 0-5 volt range of the lower level discriminator correspond to a gamma ray energy range, say 0-1 MeV. Once this correspondence has been established, the odometer-type scale of the lower level discriminator can be interpreted in terms of gamma ray energy by a simple multiplication of the indicated scale reading by the calibration factor.

As in the method described earlier, a point connecting the two scales is found by measurement of a known standard. When Cs-137 is the standard used, the 662 keV peak is the reference which is positioned within the 0-5 volt range such that this peak lies at the midpoint of the ΔE window, and this midpoint is located at 662/1000 of its total travel:



$$E_{min} + \frac{\Delta E}{2} = \frac{662}{1000}(5)$$

Suppose we select $\Delta E = 0.10$ volts, a width broad enough so that count rate with a 1 microcurie source will permit rapid observation, yet a width narrow in comparison to that of the photopeak. The lower level discriminator voltage is then computed to be 3.26 volts.

$$E_{min} = \frac{662}{1000}(5) - \frac{0.10}{2} = 3.31 - 0.05 = 3.26 \text{ volts.}$$

The actual count rate maximum is the point where the window straddles the 662 keV energy peak, and it is this point which is the desired reference connecting the lower level discriminator's voltage scale and the gamma ray energy scale.

The 5201L's discriminators are extremely stable with both temperature and line voltage variation. The change in the input discriminator (over its full scale) will be less than 0.01%/°C for a temperature range of 0-55°C and for a line voltage variation of ±10% from 115 or 230 volts. After the initial voltage-energy calibrations are made for a particular measurement setup, this stability assures highly accurate day-to-day measurements.

The detailed procedure that follows will describe how the system gain is adjusted to accomplish the desired calibration. As before, the equipment arrangement is that shown in Figure 7, and the first step is to bring the 662 keV peak within range of the discriminators.

Procedure

1. Set controls as follows (see Appendix for front and rear panel views):

5201L	Rear Panel
AC POWER: On	STORAGE: Normal
PHA MODE: ∫ (Integral)	E_{min} BIAS: Normal
E_{min}: 3.26 volts	GATE: Normal
POLARITY: +	

DISPLAY-PRESET: Display Count - Preset Time, sec
SAMPLING MODE: Auto
PRESET "N" SWITCHES: 1.0 (sec)

5551A

POLARITY (Rear Panel): +
VOLTAGE RANGE: 765
VERNIER: Fully counterclockwise
AC POWER: On

10613A

GAIN: X10 or X100, as desired.

Note: the calibration is valid only for the gain setting used during calibration.

2. Increase the high voltage in 85-volt steps by clockwise resets of the VOLTAGE RANGE control (keep the VERNIER fully counterclockwise, at which position it is switched out.) At each new voltage setting, observe the count. Note the voltage where there is a sudden increase in the number of counts. For example, the observations might be as follows:

High Voltage	Counts per sec
765	1
850	2
935	2
1020	31
1105	3165

The actual count depends upon a number of factors including source strength, geometry, and gain setting; the significant observation is the large jump in count rather than count value. The operator now knows that with the high voltage set somewhere between 1020 and 1105 volts, the photopeak will lie at the desired position. He should now refine the high voltage setting by use of the 5551A's VERNIER control and the 5201L's PHA ΔE MODE.

3. Reset the VOLTAGE RANGE control to 1020 and the PHA MODE switch to ΔE = 0.100 volts. Rotate the VERNIER slowly clockwise to increase the high voltage, watching for the sudden jump in count and for the maximum count rate. Where this occurs, read the high voltage by pressing the VERNIER SCALE pushbutton (refer to the Appendix for details). Note this high voltage reading: 1092 volts.

4. Try another pass to more precisely determine this high voltage, increasing the time of each count to reduce statistical error.

Note

During any count accumulation period when either the high voltage setting or one of the discriminators is changed, the count displayed is apt to be in error. When the VERNIER SCALE pushbutton is depressed, the high voltage may be perturbed and noise may be introduced, also leading to a possible count error. Therefore, in such cases, press the RESET button.

Change the preset "N" switches to 5.0 (sec). Read the count at each of three 2-volt increments, for example:

High Voltage	Counts per 5 sec
1090	7864
1092	8412
1094	7953

Since the count maximum is found at 1092 volts, it is confirmed that the photopeak has been observed. Should this maximum count not lie at the middle reading of the three, repeat Steps 3 and 4. Note the exact high voltage setting where the maximum count rate is found.

5. Make a final recheck of the calibration by setting the high voltage at the level just determined and observing the count at three values of E_{min} centered on the predicted value, 3.26 volts.

E_{min}	Counts per 5 sec
3.21	7626
3.26	8450
3.31	7953

Since the maximum lies at the predicted value, 3.26 volts, the calibration is confirmed. If this is not the case, the operator should repeat steps 3, 4, and 5 with a new predicted value for E_{min} based upon the observations just made.

The result of this procedure is that the gamma ray spectrometer is now calibrated over the range of gamma ray energies 0-1 MeV. The calibration factor is 0.2 MeV per volt.

This same basic procedure can be adapted for the establishment of other calibration factors, for example, 0.3 MeV per volt, 1.5 MeV full scale. Also, standards other than Cs-137 can, of course, be used.

With the high voltage set to the value determined, and with the scintillation detector's gain (X10 or X100) at the same setting used during the calibration procedure, the odometer scale of the lower level discriminator can now be interpreted in terms of gamma ray energy. Suppose it is desired to identify an energy peak of an unknown isotope. The user determines the energy of this peak by locating the mid-window reference where the count is a maximum, and then simply multiplies by the calibration factor.

GRAPHICAL ESTIMATION OF HIGH VOLTAGE SETTING

The high voltage setting which will calibrate the 5201L's discriminators to a desired range of gamma ray energy can be estimated to within ±10 percent by use of the graphs presented in Figures 8 and 9. Figure 8 applies to energy ranges from about 1 MeV up to 10 MeV, while Figure 9 is useful for lower energies up to about 500 keV.

These plots relate high voltage settings (volts, horizontal axis) to full scale gamma ray energies (MeV or keV, right-hand vertical axis) and to calibration factors (MeV/volt, left-hand vertical axis). The slope each plot displays is the average of a number of determinations made with Hewlett-Packard scintillation detectors. Slope variations were found to be small, an indication of the desirability of the selection of premium photomultiplier tubes.

These graphs are general to the Series 10600A Scintillation Detectors and must be made specific to the user's own detector before they can serve their purpose. This the user accomplishes by determining for each graph the values of high voltage which apply to the horizontal axis. How this is done will be described with relation to Figure 8.

It first is necessary to find the high voltage setting of the 5551A which corresponds to an energy of 5 MeV full scale. This high voltage, which varies from detector to detector, usually is in the range 500-700 volts. It is designated V_c on Figures 8 and 9. It may be determined by use of the procedure described under "Calibration to a Selected Range of Gamma Ray Energy". The predicted value of E_{min} to place the Cs-137 peak at the desired mid-window reference is 0.612 volt for ΔE = 0.1 volt:

$$E_{min} = \frac{5\,(0.662)}{5} - \frac{\Delta E}{2} = 0.662 - 0.05 = 0.612 \text{ volt}$$

The value of the high voltage setting which has been determined is now substituted for V_c on the graph's high voltage scale, horizontal axis. The other major graduations of this scale become $V_c \pm 100$, $V_c \pm 200$, etc. For example, suppose V_c = 570 volts. The major graduations relative to this value would become 370, 470, 570, 670, and 770 volts.

An example set out with a dashed line makes clear how the graph is used. Assume the user desires to set a spectrometer to cover the gamma ray energy range 0-1.5 MeV. He has found that V_c = 520 volts. He enters the graph at 1.5 MeV along the right-hand vertical scale, traces straight left to the diagonal line, and from this intercept straight down to the horizontal scale where he reads the desired value to be 643 volts (520 + 123).

The graph's left-hand vertical scale shows the calibration factors corresponding to the full scale gamma ray energies on the right-hand scale and is useful to estimate a calibration factor for a known high voltage setting.

Figure 9 shows the graph for use at lower gamma ray energies; it serves the same purpose as Figure 8, for energy ranges from 0-60 keV up to 0-600 keV. To gain accuracy for this lower energy range, the 31.5 keV peak of Cs-137 is used as the reference. The procedure for establishing the value of V_c is otherwise the same as discussed earlier. Again, the predicted value for E_{min} is 0.612 volt with $\triangle E$ at 0.1 volt.

Since these graphs were prepared with the GAIN switch of the Series 10600A Scintillation Detector set at X100, they apply only for a X100 setting. Note that V_c must be redetermined if the photomultiplier tube is changed.

CALIBRATION PROCEDURE CHECK LIST

The steps necessary to calibrate the 5201L, the 5551A, and any one of the Series 10600A Scintillation Detectors are summarized on the pages to follow. Users may wish to reproduce these two pages for use as a check-off card.

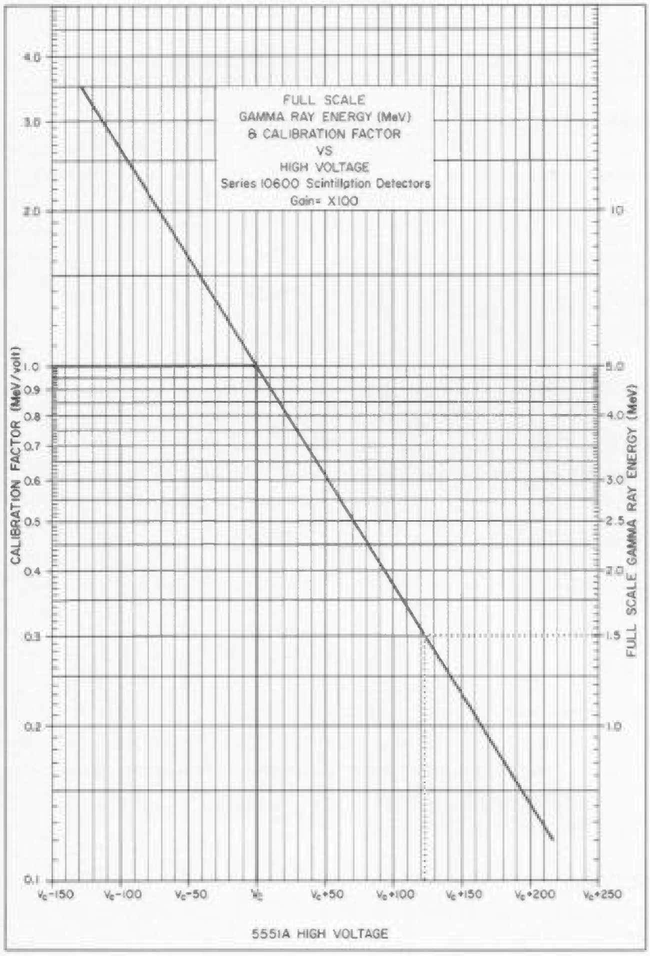


Figure 8. Relationship of full-scale gamma ray energy (MeV), calibration factor, and high voltage. The value of V_c (typically 500-700 volts) that applies to the horizontal axis must be found for the photomultiplier-detector being used (see text). The 662 keV peak of Cs-137 is the energy reference.

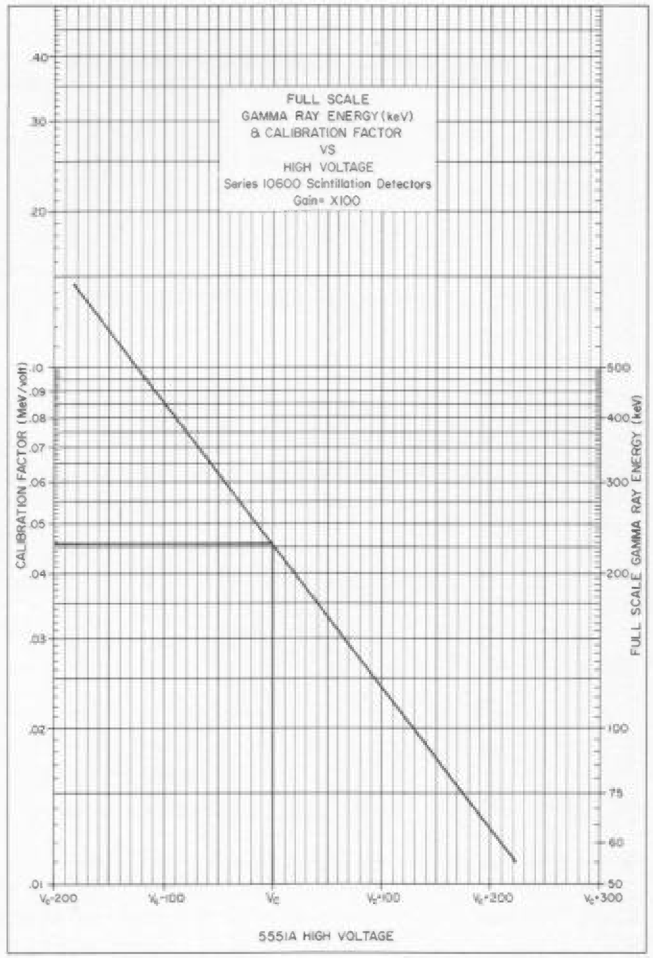


Figure 9. Full-scale gamma ray energy (keV) and calibration factor vs high voltage. V_c must be found for the photomultiplier-detector being used (see text). The 32 keV peak of Cs-137 is the energy reference.

CHECK LIST

CALIBRATION FACTOR, GIVEN HIGH VOLTAGE SETTING

SYSTEM COMPONENTS: 5201L SCALER-TIMER, 5551A HIGH VOLTAGE POWER SUPPLY, SERIES 10600A SCINTILLATION DETECTOR.

1. SET CONTROLS AS FOLLOWS:

5201L

AC POWER:	ON
PHA MODE:	$\int$ (INTEGRAL)
E_{MIN}:	4.5 VOLTS
POLARITY:	+
DISPLAY-PRESET:	DISPLAY COUNT - PRESET TIME, SEC
SAMPLING MODE:	AUTO
PRESET "N" SWITCHES:	1.0 (SEC)

REAR PANEL

STORAGE:	NORMAL
E_{MIN} BIAS:	NORMAL
GATE:	NORMAL

5551A

POLARITY (REAR PANEL):	+
VOLTAGE RANGE:	680
VERNIER:	FULLY COUNTERCLOCKWISE
AC POWER:	ON

10613A

GAIN SWITCH: X10 (OR X100)
NOTE: CALIBRATION IS VALID ONLY FOR SETTING USED DURING CALIBRATION.

2. INCREASE HIGH VOLTAGE BY CLOCKWISE STEPS OF THE **VOLTAGE RANGE** CONTROL, OBSERVING THE COUNT RATE TO FIND THE SETTING WHERE A SUDDEN INCREASE OCCURS. NOTE THIS VALUE.

HIGH VOLTAGE	COUNTS PER SEC
765 VOLTS	________
850	________
935	________
1020	________
1105	________
1190	________

HI VOLTAGE ________

3. CHANGE **PHA MODE** TO $\Delta E = 0.100$ VOLT; CHANGE PRESET **"N"** SWITCHES TO 5.0 (SEC); RESET E_{MIN} SLIGHTLY BELOW INITIAL SETTING. INCREASE E_{MIN} IN 0.1 VOLT STEPS, WATCHING FOR THE MAXIMUM COUNT.

E_{MIN}	COUNTS PER 5 SEC
____	________
____	________
____	________
____	________

4. COMPUTE THE CALIBRATION FACTOR:

$$\text{C.F., MEV/VOLT} = \frac{\text{ENERGY PEAK, MEV}}{E_{MIN} + \frac{\Delta E}{2} \text{ VOLTS}}$$

CALIBRATION

HIGH VOLTAGE ________

-CALIBRATION -

DATE ________ INITIALS ________

CALIBRATION FACTOR ________

SPECTROMETER SERIAL NOS.

HP 5201L ________

HP 5551A ________

HP DETECTOR ________

GAIN ________
(X10 OR X100)

CHECK LIST

CALIBRATION TO A SELECTED RANGE OF GAMMA RAY ENERGY

1. PREDICT E_{MIN} TO CALIBRATE SPECTOMETER TO DESIRED ENERGY RANGE. FOR EXAMPLE, TO MAKE 0-5 VOLTS CORRESPOND TO 0-1 **MEV WITH** USE OF 662 KEV C_S-137 PEAK:

$$E_{MIN} + \frac{\Delta E}{2} = \frac{662}{1000}(5)$$

2. SET CONTROLS AS FOLLOWS:

5201L

AC POWER:	ON
PHA MODE:	$\int$ (INTEGRAL)
E_{MIN} (PREDICTED VALUE)	______________
POLARITY:	+
DISPLAY - PRESET:	DISPLAY COUNT - PRESET TIME, (SEC)
SAMPLING MODE:	AUTO
PRESET "N" SWITCHES:	1.0 (SEC)

REAR PANEL

STORAGE:	NORMAL
E_{MIN} BIAS:	NORMAL
GATE:	NORMAL

5551A

POLARITY (REAR PANEL)	+
VOLTAGE RANGE:	765
VERNIER:	FULLY COUNTERCLOCKWISE
AC POWER:	ON

10613A

GAIN: X10 OR X100, AS DESIRED.
NOTE: THE CALIBRATION IS VALID ONLY FOR GAIN SETTING USED DURING CALIBRATION

3. INCREASE HIGH VOLTAGE BY CLOCKWISE STEPS OF THE **VOLTAGE RANGE** CONTROL, OBSERVING THE COUNT RATE TO DISCOVER THE SETTING WHERE A SUDDEN INCREASE OCCURS. NOTE THIS VALUE.

HIGH VOLTAGE	COUNTS PER SEC
765	______________
850	______________
935	______________
1020	______________
1105	______________
1190	______________

VOLTAGE RANGE ______________

4. CHANGE **PHA MODE** TO ΔE = 0.100 VOLT, RESET **VOLTAGE RANGE** ONE SETTING BELOW THAT FOUND IN STEP 2. ROTATE **VERNIER** SLOWLY CLOCKWISE, WATCHING FOR SUDDEN JUMP IN COUNT AND THE MAXIMUM COUNT RATE. AT THIS POINT, READ THE HIGH VOLTAGE (PRESS **VERNIER** SCALE PUSH-BUTTON).

5. TRY ANOTHER PASS TO MORE PRECISELY DETERMINE THIS HIGH VOLTAGE: CHANGE PRESET **"N"** SWITCHES TO 5.0 SEC. READ COUNT AT 2 VOLT INCREMENTS.

HIGH VOLTAGE	COUNTS PER 5 SEC
______________	______________
______________	______________
______________	______________

IF HIGHEST COUNT DOES NOT LIE AT CENTER READING OF THE THREE, REPEAT STEPS 4 & 5.

6. VERIFY THE CALIBRATION BY SETTING THE HIGH VOLTAGE AT THE VALUE JUST DETERMINED AND OBSERVING THE COUNT FOR THREE VALUES OF E_{MIN} CENTERED ON THE PREDICTED VALUE. IF CALIBRATION IS NOT CONFIRMED, REPEAT STEPS 4, 5, & 6. ENTER RESULTS IN BOX FOR FUTURE REFERENCE.

-CALIBRATION -

DATE __________ INITIALS ______________

ENERGY RANGE ______________

CALIBRATION FACTOR ______________

HIGH VOLTAGE ______________

SPECTROMETER SERIAL NOS.

HP 5201L ______________

HP 5551A ______________

HP DETECTOR ______________

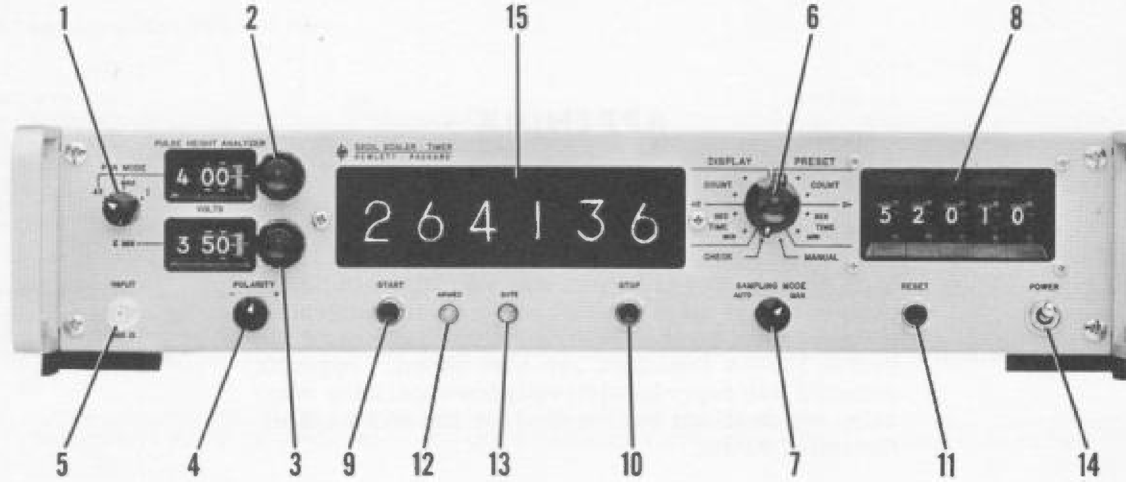
GAIN ______________
(X10 OR X100)

APPENDIX

This appendix presents front and rear panel views for the Model 5201L Scaler-Timer and the Model 5551A High Voltage Power Supply, and operating details for those modes of operation referred to in the calibration procedures. Controls and terminals for one of the Series 10600A Detectors are also shown. Appendix material was reproduced directly from operating manuals, which should be consulted for any additional information wanted.

Model 5201L Scaler-Timer Front Panel

FRONT PANEL



1. PHA MODE: selects the modes of pulse height analyzer operation: ΔE mode, E_{max} mode, $\int$ mode.

2. UPPER LEVEL DISCRIMINATOR (ULD) CONTROL: 1) determines the window width (ΔE) in the ΔE PHA MODE, 2) sets the upper level E_{max} PHA MODE, and 3) is off in the $\int$ PHA MODE. The ULD range is 0 to +.500V in ΔE PHA MODE and 0.05V to 5.0V in E_{max} PHA MODE.

3. LOWER LEVEL DISCRIMINATOR (LLD) CONTROL: 1) determines the lower level of the window (E_{min}) in the ΔE PHA MODE, 2) sets the lower level (E_{min}) in the E_{max} PHA MODE, and 3) determines the lower level in the $\int$ PHA MODE. The LLD range is 0.05V to 5.0V.

4. POLARITY: selects polarity of input pulses, facilitating operation with detectors providing either positive or negative output pulses.

5. INPUT 500Ω. Front or rear panel signal INPUT. (5.0 volts max peak pulse amplitude.)

6. DISPLAY-PRESET: selects mode of measurement: CHECK, DISPLAY TIME MIN-PRESET COUNT, DISPLAY TIME SEC-PRESET COUNT, DISPLAY COUNT-PRESET TIME SEC, DISPLAY COUNT-PRESET TIME MIN, and MANUAL.

7. SAMPLING MODE: selects AUTOMATIC or MANUAL sampling. With AUTOMATIC sampling the Scaler-Timer continuously accumulates pulses, displays, resets and arms itself for the next gating pulse. With MANUAL sampling the RESET pushbutton must clear display, preset dividers, and clock time base; and the STOP and START pushbuttons control the accumulation of pulses.

8. PRESET "N" SWITCHES: select the numbers to be displayed in DISPLAY-PRESET CHECK. In DISPLAY TIME-PRESET COUNT the Scaler-Timer counts and displays the time in seconds or minutes required for a number of counts preset by the "N" switches to be made. In DISPLAY COUNT-PRESET TIME the Scaler-Timer counts the number of input pulses for a time in seconds or minutes preset by the "N" switches.

9. START: will start the count in DISPLAY-PRESET MANUAL function. In the MANUAL SAMPLING MODE, the START pushbutton arms the gate so the next gating pulse will start the count.

10. STOP: will stop the count in any mode of operation. In DISPLAY-PRESET functions the STOP pushbutton stops and resets the Scaler-Timer. In the MANUAL SAMPLING MODE the stop pushbutton stops the count but does not reset it. The count may be started again by the START pushbutton or reset by pushing the RESET pushbutton.

11. RESET: resets display, preset decades, and clock time base.

12. ARMED LAMP: indicates that the gate is armed and ready to receive a timing pulse.

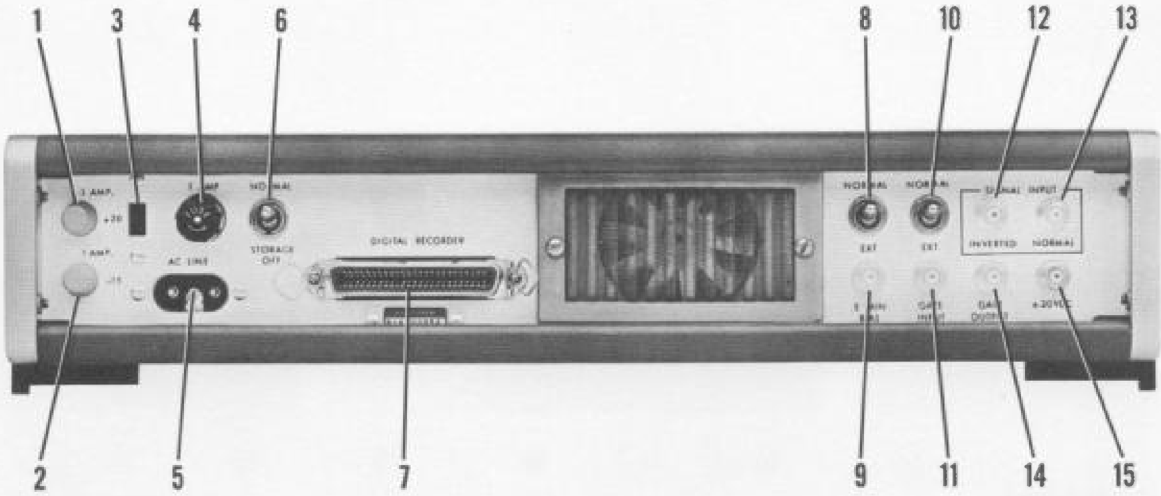
13. GATE LAMP: indicates that the gate is open and the Scaler-Timer is counting.

14. AC POWER SWITCH: turns instrument on and off.

15. DISPLAY. The six Decimal Counter Assemblies provide the display of either; 1) the input signals in DISPLAY COUNT-PRESET TIME and DISPLAY COUNT-PRESET MANUAL functions, 2) the clock time base signals in DISPLAY TIME-PRESET COUNT function or, 3) the self check signals determined by the preset "N" switches in the DISPLAY PRESET CHECK functions.

Model 5201L Scaler-Timer Rear Panel

REAR PANEL



1. +20 VOLTS SUPPLY FUSE: provides overload protection. It should be 1 ampere.

2. -15 VOLTS SUPPLY FUSE: provides overload protection. It should be 1 ampere.

3. LINE VOLTAGE SWITCH: permits selection of either 115- or 230-vac line. Slide it up for 115v; down for 230v.

4. LINE FUSE: provides overload protection. It should be 1 ampere.

5. AC LINE CONNECTOR: connects to flat plug on power cable.

6. STORAGE: provides a means of disabling the storage feature. The display storage feature provides a continuous visual display while the instrument is totalizing a new count. Only if the new count differs from the previous count will the display change, when the SAMPLING MODE is in AUTO position.

7. DIGITAL RECORDER CONNECTOR: supplies BCD information for a digital recorder, analog converter, or other data processing equipment.

8. E_{min} Bias Switch. NORMAL-EXT: disconnects the front panel E_{min} control from the LLD and allows external control of E_{min}.

9. E_{min} BIAS: controls the bias for the LLD. The voltage required to sweep the full range is 0 to 5 volts.

10. NORMAL-EXT. GATE switch: allows the user to enable the display decades with an external gate signal, when the DISPLAY-PRESET switch is in MANUAL position.

11. GATE INPUT. A +5 volt to +20 volt signal will open the gate and start the count if the NORMAL-EXT GATE input switch is on EXT and the DISPLAY-PRESET switch is on MANUAL.

12. INVERTED SIGNAL INPUT: provides a means of suppressing induced noise pickup from ground loops when the input detector is remote from the Scaler-Timer. A cable is connected to the inverted signal input with the inner conductor at the other end connected to ground at the input transducer and with the shield floating.

13. SIGNAL INPUT NORMAL: parallels the INPUT on the front panel.

14. GATE OUTPUT. A +15V level appears at the GATE OUTPUT when the gate is open.

15. +20 VDC: output, using a TNC connector, provides power to the 10600A series of scintillation detectors.

Operation - Model 5201L Scaler-Timer

PHA ΔE MODE

1. Set PHA MODE selector to Δ E.

2. Set upper level discriminator control to desired Δ E (window width), range is from .000 to +.500v.

3. For use as a Manual Spectrometer set lower level for desired E_{min} (lower window level), range is 0.05v to 5.0v.

   Note: All pulses between E_{min} and $E_{min} + \Delta E$ will be totalized by the Scaler-Timer.

4. For use as a Scanning Spectrometer, set rear panel E_{min} BIAS switch to its EXT position and apply external scanning control voltage (0 to 5 volts) to E_{min} BIAS connector.

5. Set POLARITY switch to + for sources providing positive input pulses and - for sources providing negative input pulses.

6. For normal signal input: connect input signal from the source to either the front INPUT connector or the rear panel NORMAL SIGNAL INPUT connector. *

7. For guarded signal input: connect a cable from the SIGNAL INPUT NORMAL connector (rear panel) to the signal input source. Connect a cable from the SIGNAL INPUT INVERTED connector (rear panel) with the inner conductor at the other end connected to ground at the signal input source with the shield left floating at the signal source (not connected to ground). *

* Maximum Input Levels.
AC: 5 volts maximum peak pulse amplitude
DC: 25 volts dc maximum level

Operation - Model 5201L Scaler-Timer

PHA ∫ MODE

1. Set PHA MODE selector to ∫ (integral).

2. Set lower level discriminator level to desired E_{min}.

   Note: All pulses above E_{min} will be totalized by the Scaler-Timer.

3. Set POLARITY switch to + for sources providing positive input pulses and - for sources providing negative input pulses.

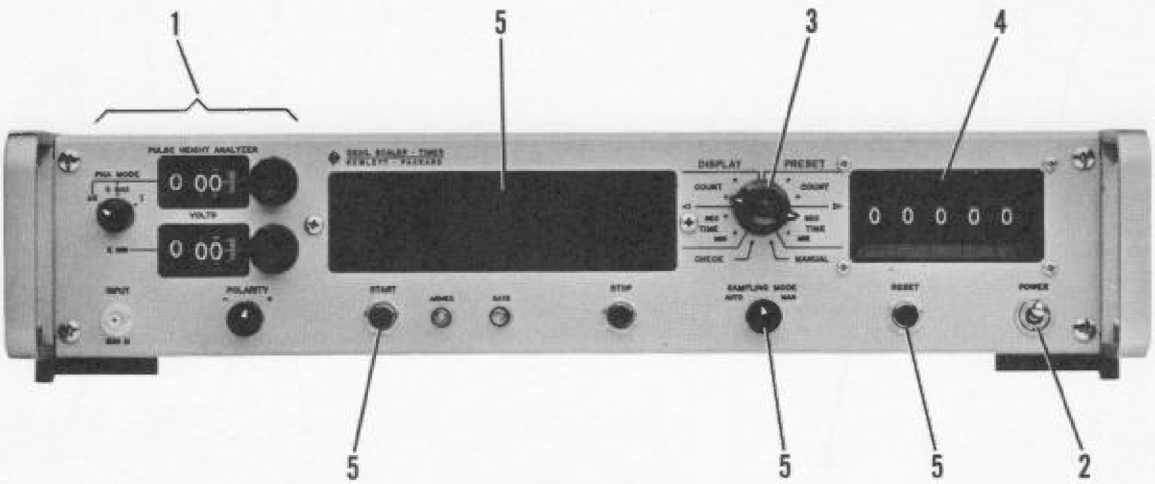
4. For normal signal input: connect input signal from the source to either the front INPUT connector or the rear panel NORMAL SIGNAL INPUT connector. *

5. For guarded signal input: connect a cable from the SIGNAL INPUT NORMAL connector (rear panel) to the signal input source. Connect a cable from the SIGNAL INPUT INVERTED connector (rear panel) with the inner conductor at the other end connected to ground at the signal input source with the shield left floating at the signal source (not connected to ground). *

* Maximum Input Levels.
AC: 5 volts maximum peak pulse amplitude
DC: 25 volts dc maximum level

Operation - Model 5201L Scaler-Timer

PRESET TIME OPERATION



1. Connect input signal and set up desired Pulse Height Analyzer Mode as described in Figures 3-3 to 3-5.
2. Turn POWER selector to ON.
3. Set DISPLAY-PRESET selector to PRESET TIME (SEC or MIN). (The number of counts made for the preset period of time is displayed.)
4. Set preset "N" switches for desired counting period in time (SEC or MIN). The decimal point is positioned to permit reading the "N" switch setting directly in SEC or MIN.
5. Select desired SAMPLING MODE. In AUTO SAMPLING MODE the Scaler-Timer will totalize and display the count measurement, then reset and start the cycle again. In MAN SAMPLING MODE pushing the START pushbutton will start the counting cycle and the Scaler-Timer will totalize the display and hold the count measurement. The Scaler-Timer can now either be reset by pushing the RESET pushbutton and a new counting cycle started or a new counting cycle can be started without reset, in this case the new count measurement will be added to the previous count measurement.

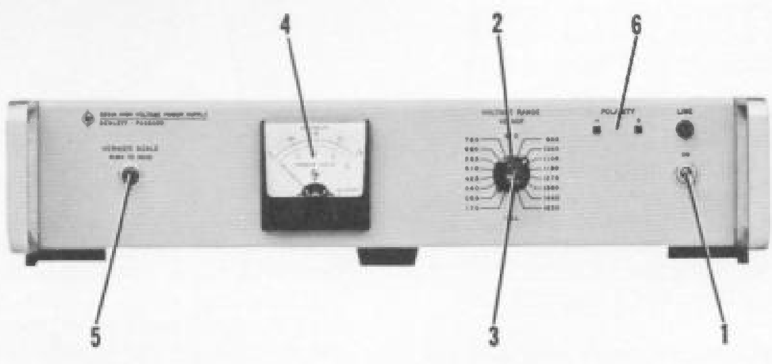
Model 5551A High Voltage Power Supply - Front & Rear Panel Views

1. AC Power Switch. The ac power switch turns instrument ON and OFF. LINE indicator indicates ac power on.
2. Voltage Range Selector. The VOLTAGE RANGE selector selects the voltage range of the power supply in 85 volt steps from 170V to 1530V.
3. Vernier Control. The VERNIER control provides voltage adjustment between the 85V VOLTAGE RANGE steps.
4. Front Panel Meter. The front panel meter reads either the total power supply output voltage, or (with VERNIER SCALE pushbutton depressed) vernier supply voltage.
5. Vernier Scale Push to Read. Pressing the VERNIER SCALE pushbutton enables operator to read vernier supply voltage on front panel meter.
6. Polarity Lamps. The POLARITY lamps indicate the polarity of the output voltage, determined by the rear panel POLARITY switch.
7. Line Voltage Switch. The line voltage switch selects either 115-V or 230-V ac line; insert narrow blade and slide to the left for 115-V; or slide to the right for 230-V operation.
8. Line Fuse. The line fuse provides overload protection: should be 1 amp for 115V, and 1/2 amp for 230V operation.
9. AC Line Connector. The AC line connector connects to the flat plug on power cable.
10. Polarity Switch. The POLARITY switch selects the polarity of the output voltage at the rear panel connectors.
11. High Voltage Output. The high voltage output connector supplies high voltage to Scintillation Detectors. Use hp 10516A high voltage cable which has high voltage BNC connectors.

WARNING

Dangerous voltage may exist on output jacks.

12. Stabilizer Input Only. The stabilizer input provides a connection for an external stabilization circuit.



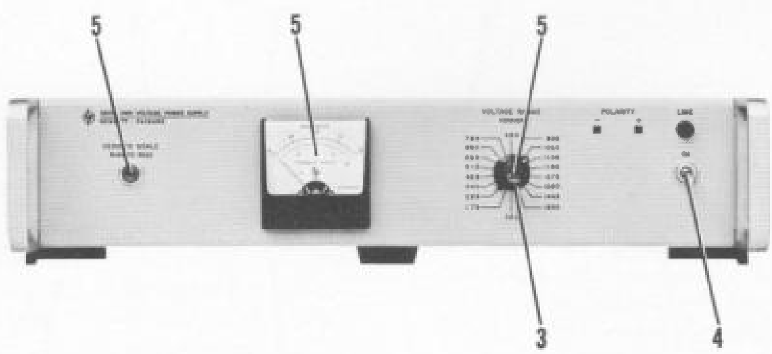
Model 5551A High Voltage Power Supply - Operation

The Model 5551A High Voltage Power Supply provides the high voltage (170V to 1614V at 1 ma) requirements of the photomultiplier tube in a scintillation detector. A VOLTAGE RANGE selector switch selects voltage output in 85 volt steps and a VERNIER control permits voltage adjustment between steps. The front panel meter reads the output voltage of the power supply, or the vernier supply when the VERNIER SCALE pushbutton is pressed. The illustration below provides a step-by-step procedure for operation with Hewlett-Packard scintillation detectors (HP 10601A, 10602A, 10611A, 10612A, 10613A, or 10614A).

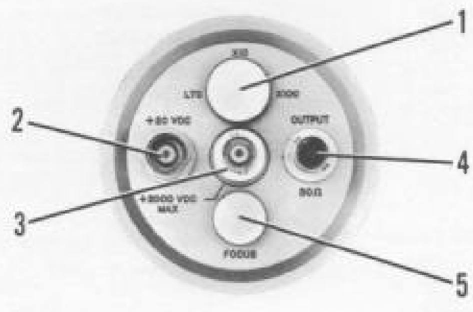
1. Connect high voltage BNC to BNC cable; one end to HIGH VOLTAGE OUTPUT connector and the other end to hp Scintillation Detector.
2. Set POLARITY to the positive polarity (+) position.

   CAUTION: Use only high voltage BNC to BNC cable (hp 10516A) which has high voltage BNC connectors.
3. Set VOLTAGE RANGE to range within 85 volts (below) of desired voltage.
4. Turn AC power on.

   Note: Front panel meter reads the power supply output voltage, or the vernier supply voltage when the front panel VERNIER SCALE pushbutton is depressed.
5. Push VERNIER SCALE pushbutton and adjust VERNIER control for a reading on the vernier meter scale equal to the difference between the desired voltage and the VOLTAGE RANGE setting. Release the pushbutton and the full value of the desired voltage will appear on the meter (fixed plus variable).



Model 10600A Scintillation Detectors - Terminals and Controls



1. Gain Switch (LTC-X10-X100). Selects the three levels of gain. The long time constant position (LTC) is used when the detector is connected to an external linear amplifier, which is usually required for high counting rates requiring high resolution. With the short time constant positions, pulses are shaped to optimize the detector's resolution at high counting rates on both the X10 (gain 10) and X100 (gain 100) positions. To provide access to the gain switch, unscrew and remove the threaded plug.

2. +20 VDC Input Jack. The +20 VDC required for operation of the preamplifier section of the detector is connected to the +20 VDC "TNC" connector.

3. +2000 VDC MAX Input Jack. The available high voltage required for operation of the photomultiplier tube is connected to the +2000 VDC MAX high voltage BNC connector.

CAUTION

Use only high voltage BNC to BNC cable.

4. 50 Ω Output Jack. The 50 Ω output BNC connector provides positive output signals to drive the electronic scaler. Maximum unloaded outputs are: +4 volts for LTC position, +10 volts for X10 and X100 positions.

5. FOCUS. This control has been adjusted for optimum resolution at the factory. Should further adjustment be required, see adjustment procedure, Paragraph 4-9, in the Maintenance Section.

OPERATION

a. Set Gain switch to desired position (LTC-X10-X100). Unscrew and remove plug to gain access to switch.

b. Connect TNC to TNC cable from +20V TNC on Scintillation Detector to +20V TNC jack on rear panel of HP Scaler-Timers, or Scaler (5201L, 5202L, or 5203L).

c. Connect high voltage BNC to BNC cable from +2000 V DC MAX BNC jack on Scintillation Detector to output BNC jack on HP High Voltage Power Supply (5551A).

d. Connect BNC to BNC cable from OUTPUT BNC jack on Scintillation Detector to Signal Input BNC jack on Scaler-Timer (5201L, 5203L, or 5203L).

e. Turn on High Voltage Power Supply and Scaler-Timer or Scaler. Adjust High Voltage Power Supply for optimum value for a given sample and mode of operation.

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DENMARK
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INTO O/Y
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Tel: 6971

Hewlett-Packard VgmbH
Lietzenburger Strasse 30
1000 Berlin 30
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GREECE
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Klaftmonos Square, Athens 124
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Tel: (020) 13.28.98 and 13.54.99

NEW ZEALAND
Sample Electronics (N. Z.) Ltd.
8 Matipo Street
Onehunga S. E. 5, Auckland
Tel: 565-361

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Ingeniorfirma
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Panama City 5, Panama
Tel: 3-0833

PERU
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Casilla 3061
Lima
Tel: 78745

PORTUGAL
TELECTRA
Rua Rodrigo da Fonseca 103
P.O. Box 2531, Lisbon 1
Tel: 68 60 72 and 68 60 73 and 68 60 74

PUERTO RICO & VIRGIN ISLANDS
San Juan Electronics, Inc.
150 Ponce de Leon, Stop 3
P.O. Box 5167
Pta. de Tierra Sta., San Juan 00906
Tel: 725-3342, 724-4406

SPAIN
ATAIO, Ingenieros
Enrique Larreta 12, Madrid 6
Tel: 235.43.44 and 235.43.45

SOUTH AFRICA
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Rosella House
Buitencingle Street, Cape Town
Tel: 3-3817

SWEDEN
H-P Instrument AB
Centralvagen 28, Solna, Centrum
Tel: 83.08.30

H-P Instrument AB
Idunagatan 28A
Goteborg
Tel: 27 68 00 and 27 68 01

SWITZERLAND
Max Paul Frey
Wankdorffeldstrasse 66, Berne
Tel: (031) 42.00.78

TAIWAN (FORMOSA)
Hwa Sheng Electronic Co., Ltd.
21 Nanking West Road, Taipei
Tel: 4 6076, 4 5936

TURKEY
TELEKOM Engineering Bureau
P.O. Box 376—Galata, Istanbul
Tel: 49.40.40

UNITED KINGDOM
Hewlett-Packard Ltd.
Dallas Rd., Bedford, England
Tel: Bedford 68052

VENEZUELA
Citec, C. A.
Edif. Arisan-Of #4
Avda. Francisco de Miranda-Chacaito
Apartado del Este 10.837, Caracas
Tel: 71.88.05

YUGOSLAVIA
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Brussels 15, Belgium
Tel: 35.29.58

For Sales and Service Assistance in Areas Not Listed Contact:

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Cable: HEWPACKSA

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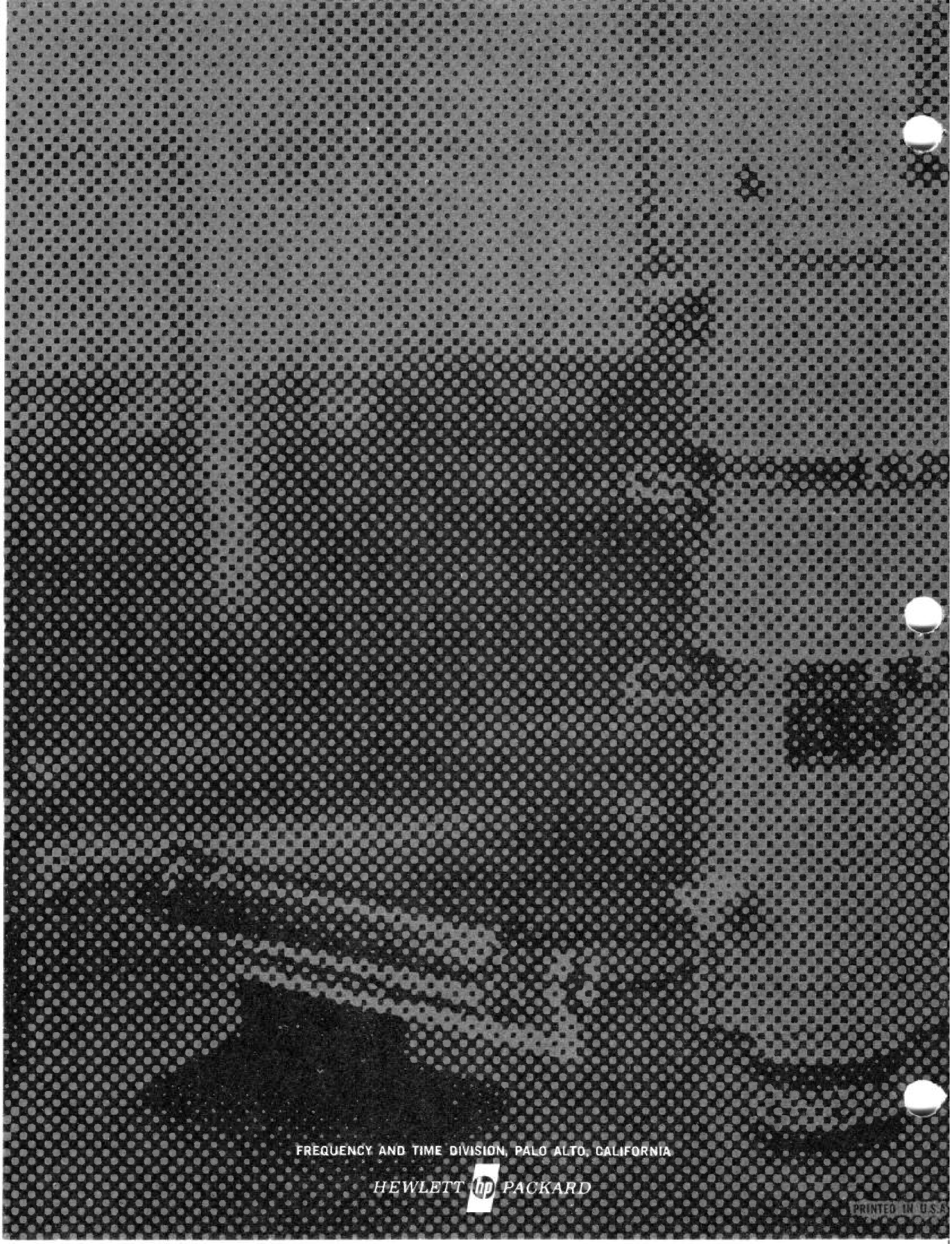

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