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USER MANUAL

for the

MTS-100 PRE-AMPLIFIER-DISCRIMINATOR

September 12, 1992

MTS-100 Preamplifier.

The MTS-100 Preamplifier is designed to amplify minute pulses from Photomultiplier tubes, Electron multipliers and similar detectors, to produce standard TTL pulses for counting application.

The MTS-100 also includes a decoupling H.V. network necessary to fulfill the detector bias requirements. It features a low pass filter in the H.V. path to lower any noise there may be on the H.V. line. The filter is especially crucial when the positive H.V. biasing scheme is utilized.

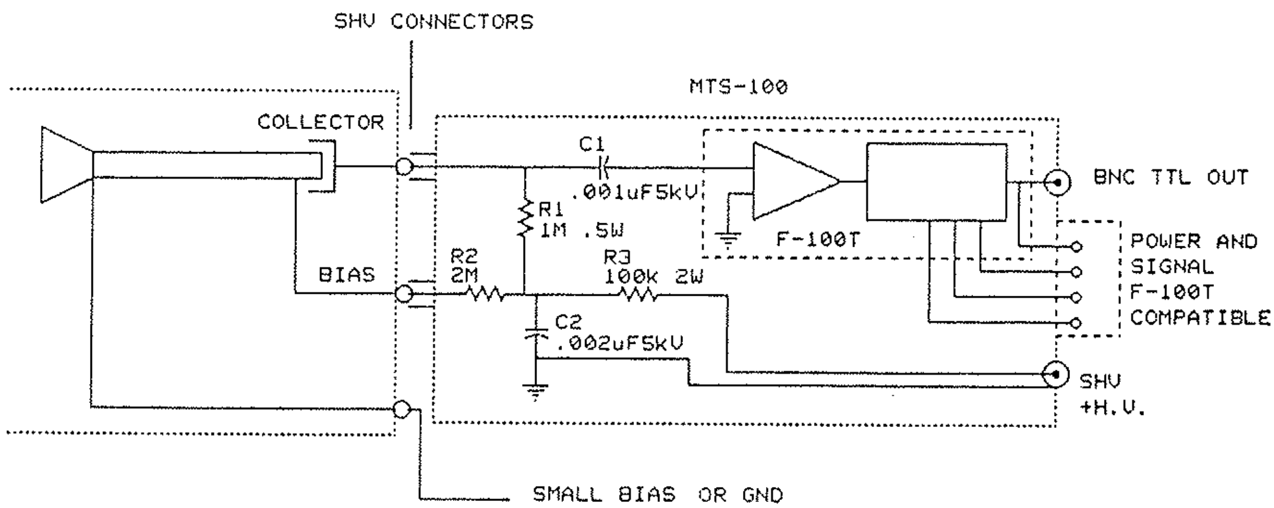


Fig.1 Detailed H.V. biasing diagram of MTS-100.

The H.V. bias illustrated in fig.1 requires positive High voltage for the detector to have its collector at more positive potential then the front of the electron multiplier.

This biasing scheme has several advantages over a negative biasing scheme:

a. Since the detectors entrance is close to the ground potential and it's not committed, it may be biased up to several hundred volts negative by additional supply, to attract positive ions or other positively charged particles. By changing the polarity of such additional bias supply, we simply switch the system to detect negatively charged particles. However, when using such an additional bias , we must remember to change the detectors bias accordingly since both supplies are typically grounded (referenced to ground).

When using a floating (uncommitted) high voltage supply for the detector, switching from positive to negative particle detection is much simpler. All we have to do,is to change the entrance bias. Although in this case we don't have to worry about the influence on the potential across the detector, it is absolutely necessary to shut the supplies off,before changing the polarity of the bias supply.

b. A low bias potential at the entrance also creates low electrostatic field that is less likely to attract a variety of possible spurious charged particles generated by a field emission, thermal emission or photo emission and contribute to the background count rate. This becomes particularly important when operating at low intensities where the background is highly significant.

The positive biasing scheme however has one disadvantage. The noise (ripple) from the H.V. supply is directly coupled to the preamplifier and thus determines the lowest detection limit for the signal. It should be obvious that if the ripple is specified as 10mV peak to peak value, we cannot expect to detect any pulses smaller then that unless we want to count the H.V. ripple also.

Caution: Some H.V. supply manufacturers specify the ripple as RMS value which may be 5-10 times smaller then peak to peak value of the same ripple. Since most of the H.V. supplies today are the switching regulator type, the noise consists mostly of high but narrow shape pulses yielding rather low RMS value. It seems to be more attractive to specify low noise level in RMS value than a much higher one in the peak to peak value.

A good indication whether or not the H.V. supply we are using is too noisy is a very specific rate meter reading (the switching frequency of the supply) without signal present, with the H.V. on and the threshold of the noise discriminator safely above the amplifier - detector noise level. Although the H.V. always increases the background count rate, when the rate meter reads a stable frequency , and always the same between 20kHz and 200kHz (or Counts Per Second CPS) it is definite indication that we are counting the H.V. ripple frequency.

The RC filter in fig.1 consisting of R3 and C2 will reduce the H.V. noise level significantly,but it will not eliminate it. For the best results, a lowest noise-ripple H.V. supply is absolutely essential.

The preamplifier that follows the decoupling network is the F-100T preamplifier and its function and operation is described in the next part of this manual.

INTRODUCTION.

This manual is design to assist in the installation and operation of your F-100T preamplifier-discriminator. It begins with output considerations because of their easy applicability and continues toward the more critical input concerns.

INSTALLATION.

OUTPUT CONSIDERATIONS.

The output connector wiring diagram is self explanatory(see Fig. 4). The preamplifier requires an unregulated dual power supply ±8V to ±30 Volts; typically ±12V, ±15V or ±24V at +50mA and -30mA. Since built-in voltage regulators virtually eliminate any ripple, instability or noise on the power lines, this is the least critical connection.

The output pulses from pin 1 are the standard TTL/CMOS level: +5.0V unterminated with respect to ground (pin 6).

The output signal may need some attention to eliminate potential problems related to an improperly terminated transmission line . The output impedance of F-100T is 50 ohms, thus a 50 ohm coaxial cable terminated by a 50 ohm resistor (or connection to a (50 ohm input impedance) rate-meter should be used to avoid reflectance (ringing or multiple pulsing) that is typical for unterminated transmission lines.

The minimum output pulse width is about 10 nS. The pulse width can be extended by the addition of a capacitor C8 inside the F-100T. The required capacitor corresponding to the desired pulse width, may be determined from the graph in this manual. It is important to use minimum pulse width that can be tolerated by the rate-meter since the minimum pulse pair spacing (maximum pulse pair resolution) is directly related to the output pulse width. The relationship is quite obvious. The pulse pair resolution is limited by the output pulse width. The wider the output pulse width, the worse will be the pulse pair resolution.

There are two potential problems associated with the 50 ohm termination:

1) Some rate-meters or counters may only have a high impedance input available, therefore an external terminator must be used,i.e.

If your rate-meter does not have a 50 ohm input impedance, you can easily modify it by attaching a metal film or carbon resistor across the input. Do not use wire wound resistors as they tend to have high inductance. If modification of the input is not feasible, a BNC "Tee" Adaptor may be used with a BNC 50 ohm terminator. The 50 ohm terminators are available from ARI Corp or any major electronic supplier.

2) The terminator will reduce the pulse height to +3.0V which may not be sufficient for some rate-meters to detect.

If the +3.0V pulse height is insufficient for your rate-meter or counter, an unterminated signal connection may be considered, but only if the physical length of the coax cable is less than about one meter. The shorter the connection, the safer it is to use the unterminated cable. The decision whether or not to use terminated cable must be based on the input specifications of the considered counter-timer-ratemeter. A fast and sensitive rate meters (>20 MHz, with sensitivity <1V) always require proper termination. A relatively slow rate meters usually have an input sensitivity control or a threshold adjustment that may be used for input signals .1V to 25V and high input impedance. In this case , an external termination for a short cable may not be necessary but nevertheless recommended. The 3.0V signal level,with properly adjusted input threshold to about 1V will be the best solution. A long cable (>5 meters) always must be terminated.

Example of a ringing reduction by termination:

	unterminated		terminated	
	pulse height	ringing	pulse height	ringing
2 m cable	+ 5.0V	+1.5V-2V (3.5Vp-p)	+ 3.0V	+.2-.2V (.40Vp-p)
8 m cable	+ 5.0V	+.8V-1.8V (2.6Vp-p)	+ 3.0V	+.2-.2V (.40Vp-p)

The example illustrates a 6-8 fold improvement of ringing or the reflectance, for a terminated cable compared to an unterminated one. The most significant value is the positive excursion of the ringing value, since the tripping threshold for the TTL signals is +.7V minimum the +1.5V glitch on the 2 meter unterminated cable will very likely produce a double pulsing. The problem is most severe when a high frequency and high sensitivity counter is employed. A care must be exercised in selection of the counter-timer-ratemeter so that only the signal pulses are being counted.

The measurement on the eight meter cable indicates only minor change in the ringing amplitude and opens up the possibility of using even longer cables unterminated but only if an input threshold can be adjusted safely above the ringing level.

Another solution is to use a high threshold integrated circuits such as : 7414 ,74LS14 , 74S14 , 74HC series and others on the input of your counter-timer or ratemeter.

In short, most TTL signals do not need termination unless a long coaxial cables are involved. If you terminate the cable, the ringing will be reduced approximately 6-8 times. Unfortunately, the signal will be reduced to a half its original amplitude. If this is a problem, an intermediate solution may be the answer. A 100 ohm terminator on 50 ohm cable produces only slightly larger ringing then 50 ohm terminator, but the pulse amplitude is only little less then original.

INPUT CONSIDERATIONS.

The input connection is far more critical than the output connection. Initially, high sensitivity input requires the shortest possible connection to the PMT or an electron multiplier. Also, noise induced to the input signal or input ground connection will have to be eliminated by setting the discriminator to a lower sensitivity region, thus reducing the overall performance.

Bearing on mind that the 50 uV input sensitivity of F-100T is about the same as most radio and television receivers except with a much larger bandwidth (making the situation much more critical), the preamplifier is to operate in electrically hostile environment without responding to the severe interference of switching power supplies, R.F.part of mass spectrometers, computers, SCR's etc.

Since each of the interference sources listed above is a serious threat to a interference free operation of the preamplifier,especially when they are located in the vicinity of the detector-preamplifier, a good R.F. grounding and shielding rules must be strictly observed.

The preamplifier is normally set to accept negative pulses since all PMT's and electron multipliers produce such pulses. Although the input of the F-100T is compatible with either the positive or negative biasing scheme of the PMT, the details may vary quite substantially; thus the specific bias diagram should be examined and compared with Fig. 1. Please note that there is no high voltage blocking capacitor in the F-100T. If the detector biasing system require such an isolation, it must be located outside of the F-100T preamplifier.

Finally, the input connection should preferably be done BNC-to-BNC adaptor or a very short cable. In a most severe situation even an additional ground strap may be necessary.

OPERATION.

Caution: Before applying power, it is good practice to recheck the low voltage polarity. Reversed +V with -V may destroy the pre-amplifier!

Although the input to the F-100T is protected against high voltage spikes, one should never connect or disconnect the input with high voltage bias applied to the detector.

To connect the pre-amplifier to the detector, first make the connection, then turn on the high voltage.

To disconnect the pre-amplifier from the detector, turn off the high voltage, wait 10-20 seconds and only then disconnect the pre-amplifier. If the above mentioned procedure is followed, the system will perform well and trouble free virtually forever.

DISCRIMINATOR SET UP.

The discriminator is factory set to the approximate position that works well for ARI's PMT test system. This setting may have to be changed for different systems and different bias settings.

Fig. 2 shows signal and noise that can be observed on the output of the linear pre-amplifier just before it enters the discriminator for thresholding. With the threshold trimmer fully counter clockwise, the threshold is buried in the noise (the input noise plus the noise of the pre-amplifier itself) and the F-100T produces high count rate pulses even if no signal is present. This condition is graphically illustrated in Fig 3. Note, the count-rate when the threshold is set close to zero. This situation is clearly unacceptable and the obvious solution is to increase the threshold by turning the trimmer clockwise until the noise disappears. This adjustment should be performed with the F-100T connected to the detector and the rate-meter, and with the power to the F-100T applied but without the high voltage applied to the detector. Note: If no pulses are encountered even with the discriminator fully counter clockwise, it is possible that the noise level is below the minimum detectable threshold or additional problems may be present.

With the signal source (Photons, Electrons etc.) off, turn on the high voltage and slowly increase to the approximate operating range. (If no H.V. adjustment is feasible then just turn it on). Noise should increase because the bias background is significantly higher than the noise of the pre-amplifier. Increase turning (clockwise) the threshold above the noise level. The count rate of 1 to 5 cps may be acceptable. The background count rate is usually determined by the quality of the detector or the entire experimental set-up.

Now apply the signal to your detector (PMT or electron multiplier). The count rate should increase to the correct level (assuming you know what the count rate should be). With the signal applied, turn the threshold trimmer further clockwise (increasing the threshold) and note the change in the count-rate. There should be minimal change within certain ranges i.e., the "best setting", as shown in Fig.2, until you reach the threshold setting that is too high where the count rate drastically drops off. The best setting is approximately in the middle between the noise level and loss of the signal.

If you are unable to locate the point of loosing the signal, this indicates unnecessarily high voltage to the detector that should be reduced to the level where you can observe the output change with respect to the threshold illustrated in Fig.3. The best setting range should not be greater than 2-5 turns of the threshold trimmer.

If you can not reduce the detector voltage as described above, you may operate at the higher voltage without any damage to the pre-amplifier. The reason for minimizing the bias on the detector is two fold:

a. It extends the life of the detector;

b. The detector produces narrower pulses which improves the pulse pair resolution.

With the threshold at the "Best setting" turn off the signal source (Photons, Electrons, Ions, etc.) and make sure only the background counts are present. It is good practice to check the "Best setting" at least once a year to assure that detector aging or changes in the high voltage bias do not shift the threshold out of the correct setting range.

TROUBLE SHOOTING GUIDE.

Problem 1.

No output pulses: Check the output D.C.level. If it is less then .02 Volts D.C. the output is probably shorted, disconnected or power to the preamplifier is missing. If the D.C. level is +2 to +5V, the negative supply is likely missing. If the D.C. level is -2 to -5V, the positive supply is missing. The D.C. level should be between +.1V and +.3V. If this is the case, the problem is not in the output stage and there is no reason to suspect the power supply.

Now we can turn our attention to the input stage. Disconnect the input connector, turn the threshold control fully counter clockwise and with a piece of wire touch the center pin of the input connector. This should produce plenty of signal on the output. If no signal appears at the output, the preamplifier may need to be repaired. On the other hand, if the preamplifier appears to be functioning, we should turn our attention to the detector , its power supply even to the source of electrons,ions etc. itself.

When you are certain that the detector is producing useful signal using an oscilloscope or different preamplifier, you may have to slightly increase the H.V. bias on your detector since some slower preamplifiers are even more sensitive then the F-100T and it is possible that the signal produced by your detector at this bias setting is below the sensitivity level of the F-100T.

For example: Compare the sensitivity of F-100T (1uA into 50 ohm input impedance of 10 nS minimum width to produce a standard output) to ARI's model PMT-3P a pulse preamplifier that needs an input current pulse of only 1 nA to produce a 1 Volt output pulse but it requires a pulse width of 10 uS minimum . The PMT-3P is 1000X more sensitive but it has 1000X worse pulse pair resolution. As you can see, here we are comparing 1 nA to 1 uA of sensitivity as well as 20 uS to 20 nS pulse pair resolution.

Problem 2.

Too much noise: Disconnect the input to the preamplifier, and if the noise persists, check the noise level on the positive and negative supply. Check the supply ground connection and when there is no obvious power supply problem ,the preamplifier needs to be repaired.

If the noise disappears when you disconnect the input, the noise obviously originates at the detector or in the way the preamplifier is connected to the system.

First, turn off the detector's bias supply and the source of electrons, photons etc. and reconnect the preamplifier to the detector. If the noise persists, try to locate its level by turning the discriminator trimmer clockwise until the noise disappears. If the noise is too high, to be eliminated by the trimmer, check the input connections for missing a ground or shielding connection. The input conductor must not be exposed anywhere from the detector ,to the preamplifier. Good R.F. rules must be observed so as not to turn the input connection into a receiving antenna.

Once the noise level is located, the next step is to lower it to an acceptable level via improved grounding and shielding.

When the noise level is below the minimum threshold setting,or at least close to it, turn on the detector's bias and note any changes of the noise level. A drastic increase of the noise means either noisy bias supply or H.V. insolation break down.

In this case, check the noise level of the supply,if your biasing corresponds to or is similar the fig.1a and make sure that there is a low pass filter installed in the high voltage line before it reaches the detector.(In fig.1a capacitor C1.)

Since even the best supplies may have 2-50 mV high frequency ripple that may be directly coupled to the input of the preamplifier.

If your biasing corresponds to fig.1b, you are using a negative high voltage supply and your pre-amplifier is connected to the ground side of the supply. The ripple in this arrangement is not critical because only a small portion of it will reach the pre-amplifier and in the most cases it is insignificant. The attention should be focussed to the H.V. break down effect. The most usual culprit: Contamination or device break down.

If this is not the case, the noise level is still acceptable, even with the H.V. on, turn on rest of the system, preferably one unit at a time and observe any increase in the noise level until you locate the culprit.

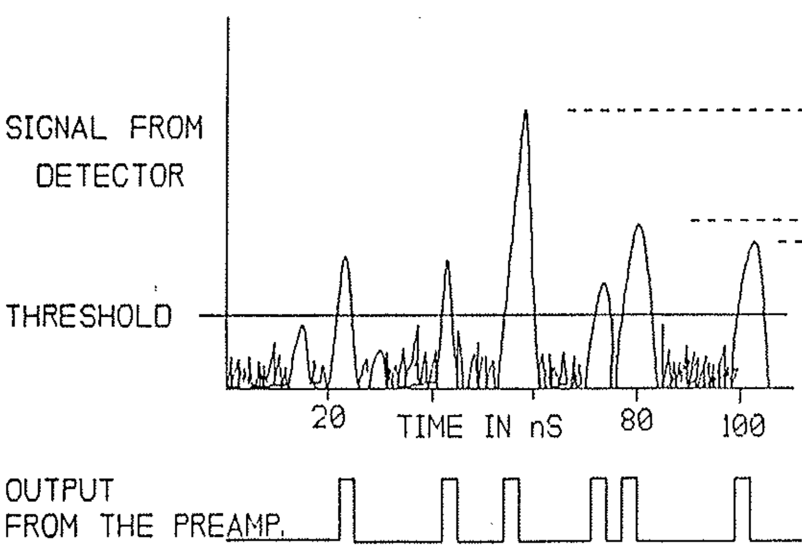
Problem 3.

Double pulsing: If you notice that the count rate is consistently about twice or even triple the rate it is supposed to be, this is usually the result of a poor connection between the preamplifier and the detector,(most likely the ground connection, mismatched impedance of various connectors,vacuum feed through devices, exposed input signal connection etc.). This results in a standing wave condition on the input of the amplifier that may produce one or more extra pulses per-each-real-one arriving from the detector.

If the problem is not too severe, rising the threshold of the discriminator will solve the problem. On the other hand, if the input connection was done disregarding good R.F. practices, the standing waves may be so severe ,that the preamplifier will enter sustaining oscillations.

The main rule that must never be compromised is : The connection from the detector to the input of the preamplifier must be done with a 50 ohm impedance coaxial cable as short as possible, <u>without exposing the center conductor</u> at feed through or anywhere else. Any compromise results in the increase of the standing wave condition (ringing) and an unnecessary high threshold level of the discriminator to avoid the double pulsing.

The double pulsing condition may also exist on the output of the pre-amplifier when a long and unterminated cable is used to connect the pre-amplifier to a counting system (rate meter etc.) This is perhaps the easiest problem to rectify. Just terminate the connection on the rate meter side with a 50Ω or 75Ω resistor and make sure there is enough signal for the counting system to use. Use 50Ω resistor for a 50Ω cable, and 75Ω resistor for 75Ω cable. If the 50Ω termination reducing the pulse amplitude excessively, you may have to resort to 75Ω cable-termination system.



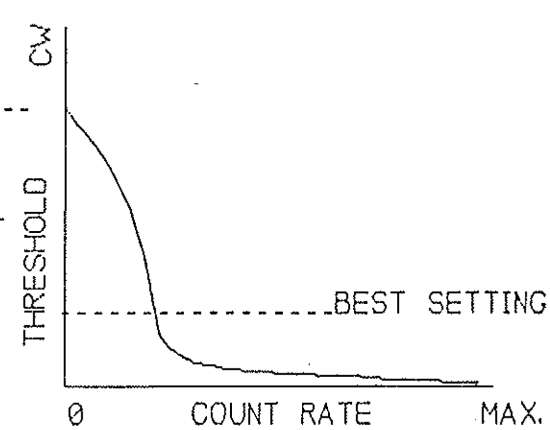
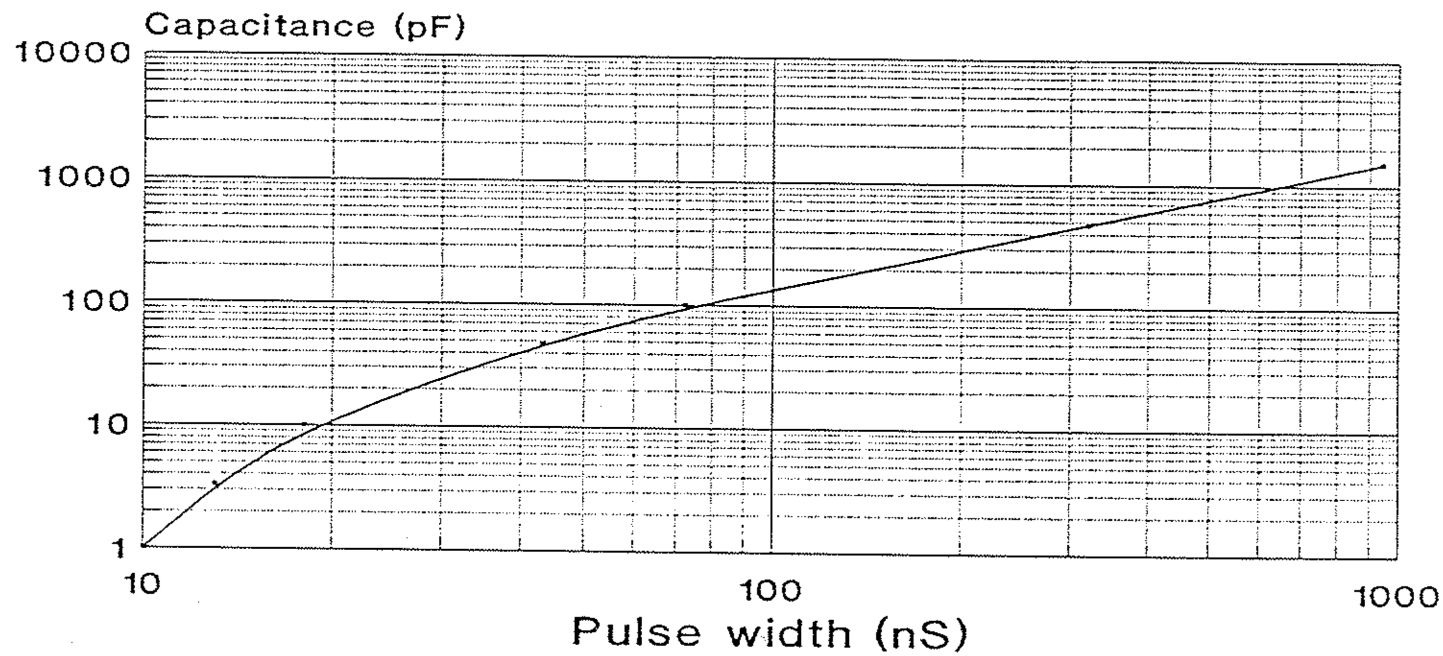


Fig.2 Signal from detector and the threshold. The resulting output from the pre-amplifier.

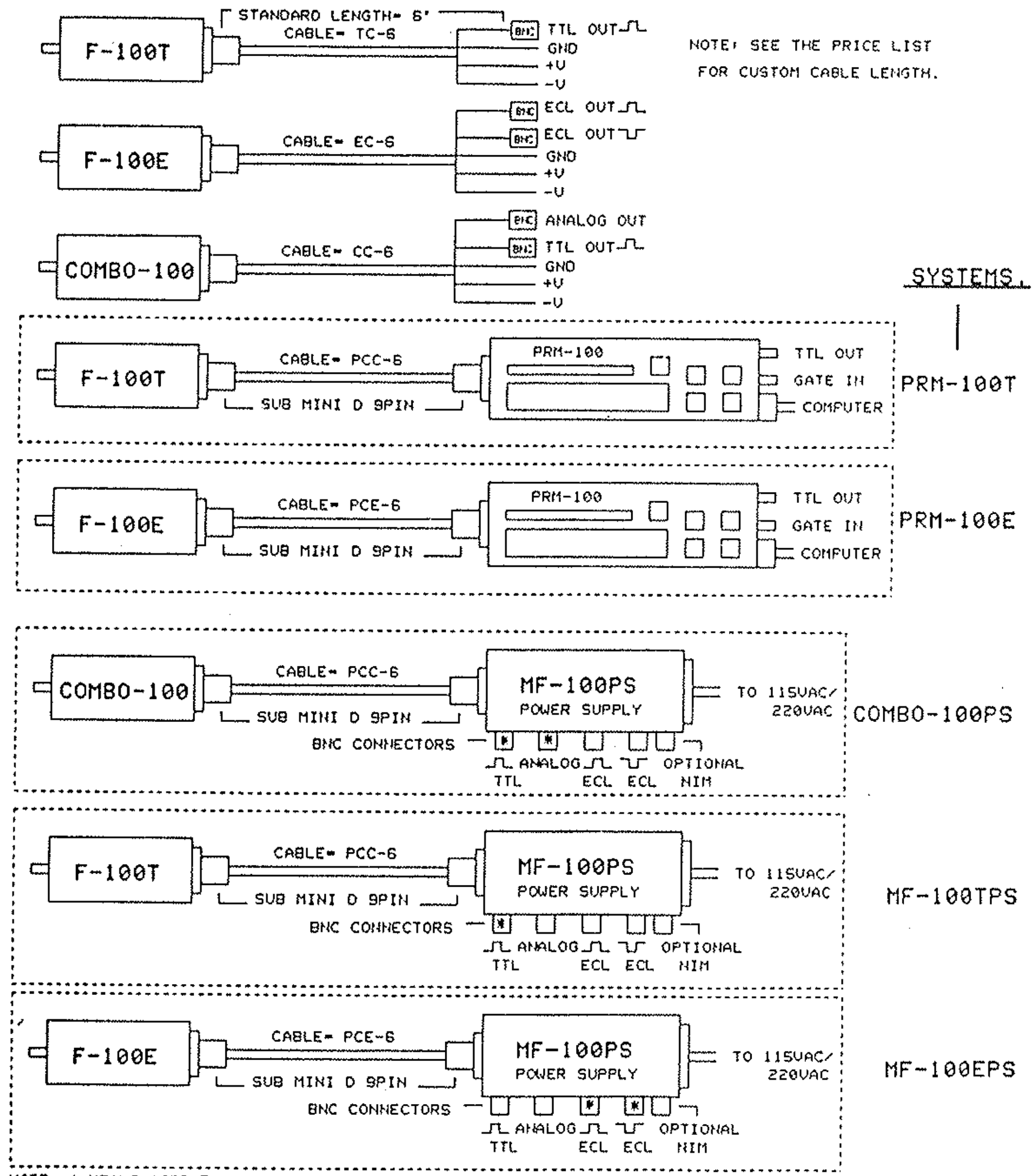
Fig.3 Relationship between the threshold position and the resulting count rate.

Timing capacitor
F-100T (V6)



F-100T

Cable selection guide.

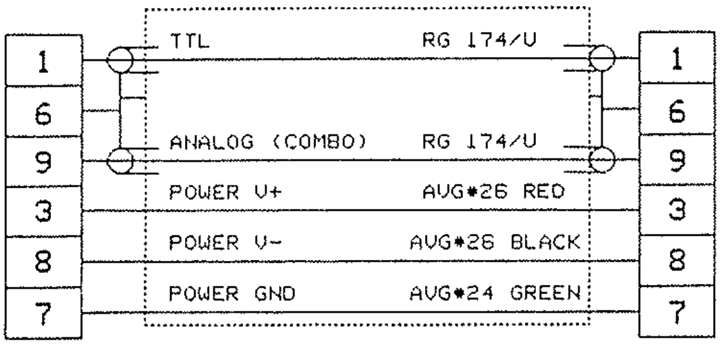


NOTE: * MEANS ACTIVE OUTPUT. ALL OTHER OUTPUTS ON THE POWER SUPPLY ARE NOT USED.
THEY ARE ONLY CONNECTED TO THE 9PIN SUB MINI D CONNECTOR.
ONLY THE NIM OUTPUT MAY BE ACTIVE, IF THIS OPTION IS DESIRED.

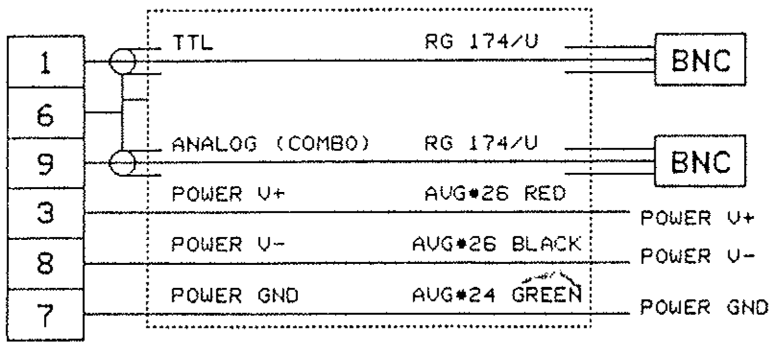
MTS-100

Cable diagrams.

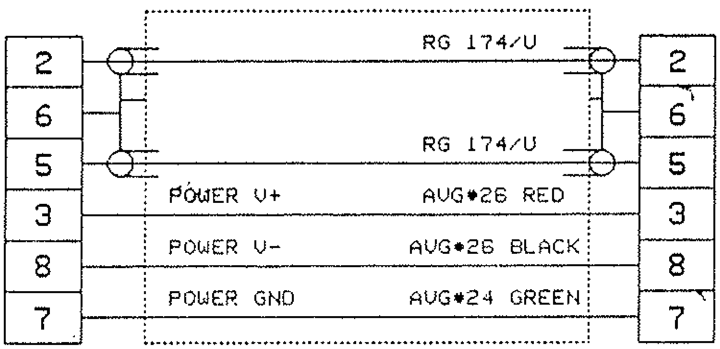
PCC-6
(TTL AND COMBO SYSTEM)



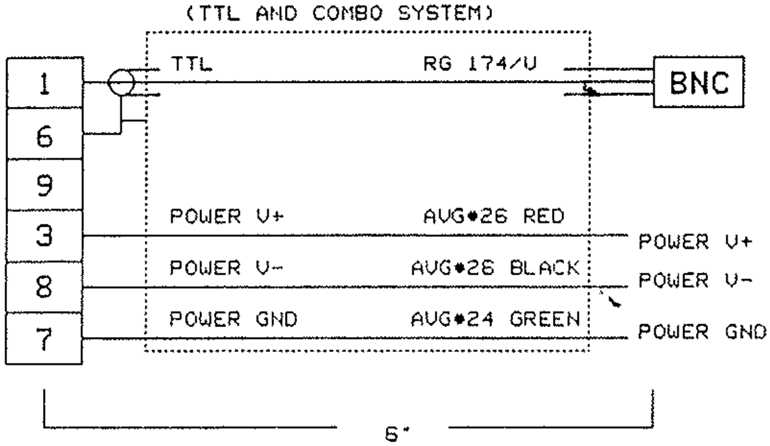
CC-6
(TTL AND COMBO SYSTEM)



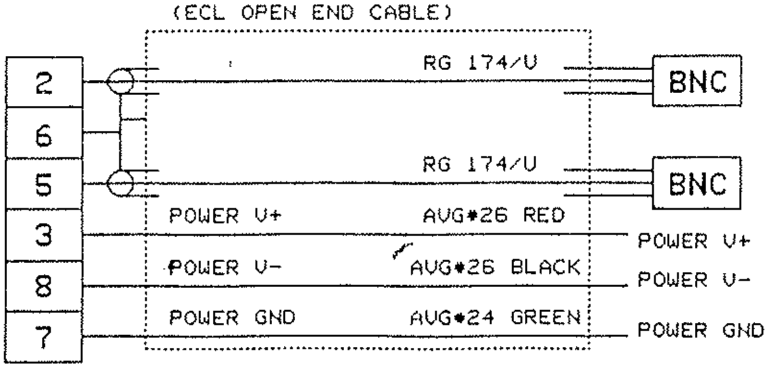
PCE-6
(ECL SYSTEM CABLE)



TC-6
(TTL AND COMBO SYSTEM)



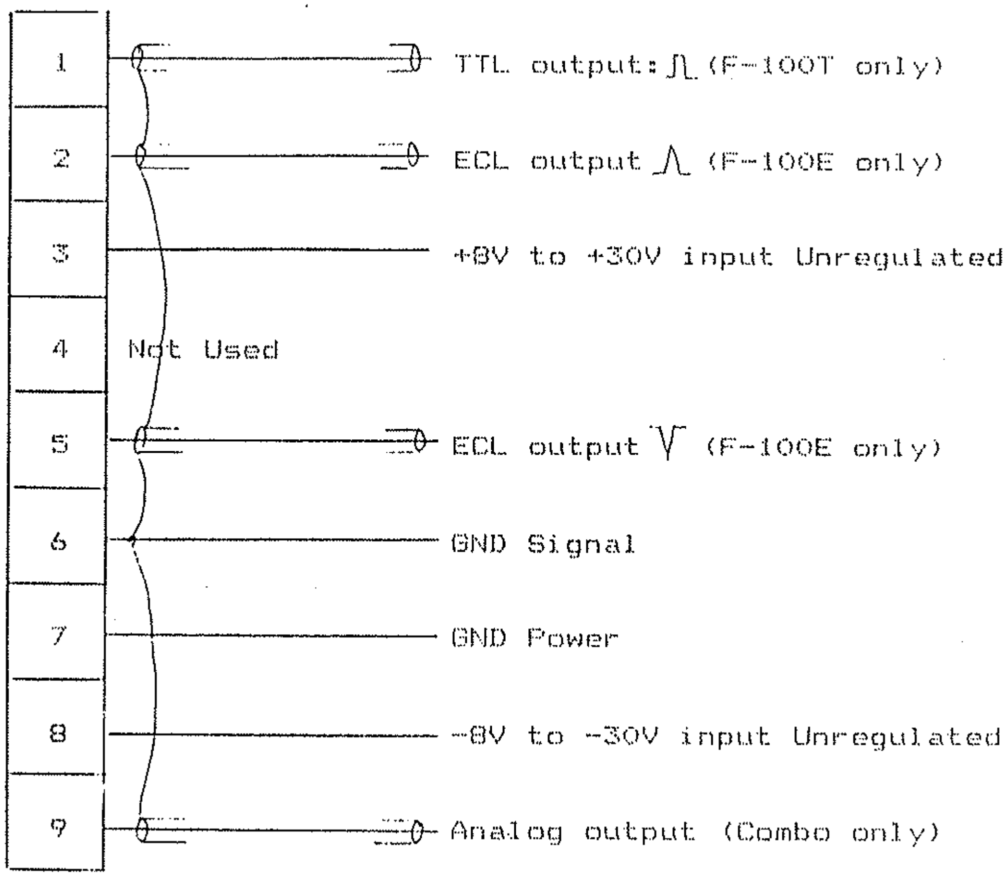
EC-6
(ECL OPEN END CABLE)



Connector : 9 Pin sub.mini D female
AMP No. 207752-1, 745002-2, 61831-1

Pins : AMP No. 1-66505-0

Pulse--Pre-amplifier F-100E and F-100T OUTPUT Connector



All coax cables RG-174/U

Connector at the pre-amplifier:
9 pin male Mini D-type AMP No. 745001-3
Recommended mating cable plug:
AMP No. 207752-1, 745002-2, 61831-1 and
pins No. 1-66505-0 or equivalent.

Fig. 4

APPLICATIONS.

Photon counting.

Very low light level measurements are best performed by counting individual photons with a Photomultiplier Tube (PMT) and associated counting electronics.

In photon counting, we are usually concerned with the background level (dark count) and the accuracy at the maximum count rates. The best photon counting systems feature the lowest background count, and the highest pulse pair resolution. The high pulse pair resolution improves the counting accuracy at high count rates, since it minimizes the error caused by pulse pile-up and resulting loss of counts.

The background count rate creates the low light level limit at the point where the photon contribution to the background count becomes smaller then the background fluctuation or more precisely,smaller then the counting error of the background.

To minimize the background:

a. Select a PMT with certified lowest dark count rate usually specified at given temperature and bias voltage.

b. Lower the operating temperature by cooling the PMT to the lowest practical level. Caution: too low temperature may result in a moisture condensation on the tube and cause problems with the high voltage bias.

c. Lower the high voltage bias to the point where the signal (incoming photons) is comfortably detected, meaning that the threshold is safely above the noise level but not too high. To accomplish this, a good preamplifier is going to be greatly appreciated. The F-100E is most likely the best choice. It combines high sensitivity and high pulse pair resolution.

d. To minimize the light leaks is so obvious that it may offend the reader. Yet, experience shows that this is the most treacherous part in an attempt to minimize the background. A simple test, such as turning the room lights off and on while noting the change of the background count rate will reveal light leaks one would not even think of.

To maximize the useful count rate limit:

a. Since the maximum count rate is limited by the pulse pair resolution, we should strive for the minimum pulse width our system can handle. The F-100E with the PRM-100 is a system capable of processing pulses only 5ns wide, that results in counting frequencies up to 100MHz. The key word here is the "frequency" rather then the"count rate". The word "frequency" implies a periodic wave form or pulses equally spaced. This however is not the case for pulses originating in most physical measurement of intensities (Ion,photon,electron counting or X-Ray intensity measurements). The pulse spacing from overlapping too long spacing can be described statistically by a distribution function, to be more specific by Poisson distribution function.

The measurement here consists of acquisition of number of counts regardless of the spacing or their distribution in time during a fixed and precise time period giving us an average number of counts per that period. This number is usually recalculated to give us a number of counts per second or"CPS".

b. For a given pulse pair resolution, it should be obvious that the closer we approach this limit, the more likely we encounter pulses closer than our pulse pair resolution and the more often we lose them. However, the loss is statistically predictable and therefore we can correct for it and push the maximum count rate a bit closer to the maximum frequency.

Automation of data acquisition

The computer interface and especially the fast parallel interface makes this system particularly easy to use as an intelligent and fully automated system when attached to virtually any spectrometer. The computer may be programmed many ways to provide the system with flexible intelligence, to adapt to the specific requirements to a particular measurement, improve accuracy, store the data for possible subsequent analyses or simply archive many spectra on a mass storage media. Fig.1 illustrates such a system.

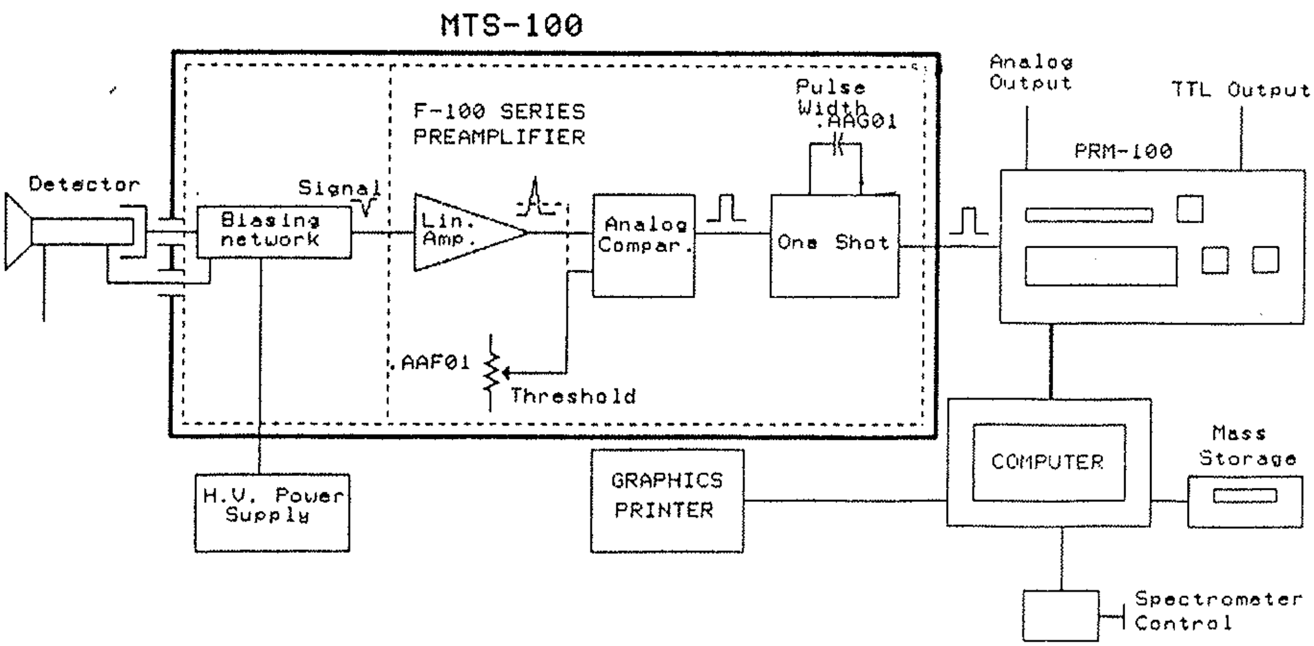


Fig.1 Block diagram of automated data acquisition system.

To control the spectrometer (to change the wave length etc.) the parallel interface provides a driver for low power stepping motor and input for a set of limit switches.

Most of spectrometers are driven by a synchronous motor producing a constant speed movement of the wave length selector shaft so that a strip chart recorder may be driven at the same speed and produce a wave length vs intensity chart.

Although the PRM-100 provides an analog output directly compatible with most strip chart recorders, and may be used in such a manner, there is a better,more accurate and easier way to do this. Any personal computer has plenty of computing power to do the data acquisition,store and plot the charts on a dot matrix printer at lower cost then the cost of a single, reasonably good strip chart recorder.

ARI Corp. has available software specifically designed for an X-Ray diffractometer to automate the acquisition of X-Ray diffraction patterns and have them readily available for further processing. The program may be easily tailored to particular spectrometers, typically without any additional expense.