Benchmark Media Systems Inc.

SPM-2/3 Instruction Manual

Table of Contents

1.0 General Overview

Audio level monitoring can take many forms these days. With a choice between LED meters of many varieties, oscilloscopes, plasma displays, and others, it's no wonder engineers are in a quandary as to what to buy.

But, we must ask questions like "Actually, where is the level"? or "Do we really know how high the peaks are"?– questions that must be answered correctly as a prerequisite to quality audio.

In some circles, the VU has fallen into disfavor because many things labeled VU are not. A true VU meter is a very expensive device, a device many cost accountants would like to eliminate.

The VU meter was designed to give a representation of the aural levels actually heard and as such it performs well. It assumes a 9 dB "meter lag" (peak to average ratio) and that this much headroom has been designed into the system. With todays program materials, headroom factors satisfactory even 20 years ago are no longer adequate. Now more than ever it is necessary to know peak amplitudes.

But the VU meter is tested and true. It is familiar. Unlike LED meters the VU meter has "infinite" resolution and is easy to read. Occasionally, however, particularly with percussion material, the VU meter can indicate a need to increase the levels, when in reality the peaks may be near clip.

1.1 A Brief History of the VU and PPM Meters

The volume indicator as developed by a joint effort between NBC, CBS and Bell Telephone Laboratories in 1939 represents a standardization that was long necessary. The problems of long line transmission, where levels were never consistent between the networks and AT&T resulted in program distortion or dynamic range compromises. Networks blamed the carrier and vice versa.

The realization of the Standard Volume Indicator, or S.V.I., now commonly called the "VU" meter, with units of measure called Volume Units, was a major step toward consistency in program interchange. The "VU" meter, developed by Bell and originally manufactured primarily by Weston, gives good representation of what is heard by the listener, the thing for which it was designed,.since it has a response characteristic that is between true RMS and average. But because the VU meter does not read peaks of program material, audio operators can find themselves in trouble with levels if enough headroom has not been designed into the system. This is due to program material which has a very high crest factor (peak to average ratio). Speech and especially percussive music can have peaks that are 16 dB or more above the VU meter's indication .

It is, therefore, most desirable to have peak reading capability, as we have previously noted, as well as VU. In this day of digital recordings compressors are used much less frequently and we no longer have the built in compression effect of analog tape. Levels must be correct. This, of course, is the rationale behind the development of the SPM-2/3 meter systems.

The meter developed by Bell is designed to give a zero indication when placed directly across a "600 ohm" line that is transmitting 1 milliwatt of audio power. This is accomplished with a 200 microamp meter movement with special ballistics, a full wave copper oxide or selenium rectifier and a precision (1%) 700 ohm series resistor. The total internal impedance of the meter is 3900 ohms. When a tone with an amplitude of 0.7746 volts is impressed across the meter terminals zero is indicated, although technically this is not zero VU. Zero VU is present only with program material, as defined by the designers of the meter.

It must be remembered that the "VU" meter is a voltage responding device, even though it is designed to work with power transmission systems. The system was designed for an additional 3900 ohms to be placed in series with the meter. With the most common power transmission systems, this comes in the form of a 3600 ohm resistor and 300 ohms of equivalent impedance from the "600 ohm" line. The inclusion of the 3600 ohm resistor provides the following features:

1.A matched impedance, so that a 3900 ohm attenuator may be placed between the 3600 ohm resistor (3900 ohm total source impedance) and the meter for calibrated readings of higher levels than with the meter alone.

2. The high source impedance provides the correct damping for the meter movement;

3. It provides further isolation of the rectifier and the resultant distortion impressed upon the transmission line;

The tone level required to indicate 0 on the "VU" meter with the addition of the 3900 ohm source impedance is +4 dBm which is 1.228 volts on the "600 ohm" line.

The "VU" meter is a totally passive system, and that was very desirable before the days of the monolithic operational amplifier. Even the 0.3% total harmonic distortion that the meter could add to the program line was considered to be inaudible. Thus its development was a major accomplishment.

1.1.1 The PPM

The peak program meter has its roots is Europe and began life in the mid 1930s. The PPM has had many differing standards, in fact almost every country in Europe has its own standard for their PPM. Today there are the EBU standards, the IEC standards, the DIN standard, the BBC standard, the Nordic standard, the CBC standard, the ABC east cost standard, the ABC west cost standard, and the British standard, among others. Some of these standards are restatements while others indeed are different. We have chosen the IEC 268-10 standard to emulate. This is the same as the DIN 45 406 (Nov 1966) standard.

Basically all PPMs have the following elements in common: They have an input amplifier and a low pass filter. They have a full wave rectifier, peak detector, and logarithmic amplifier to drive the meter movement. Where the standards typically differ is in the choice of time constants, meter lag, low pass filter parameters and especially meter scales. The total meter range is usually close to being the same, ≈ 26 dB.

Both the VU meter and the PPM have their respective advantages. The VU meter correlates very closely with what is heard by the system operator, not to mention the enormous established base of experience. The PPM shows true peaks of program material and thus relates to system overload better than the VU meter.

In the SPM-2/3 meter system we have chosen the VU meter as primary metering. The PPM section, therefore must conform to the meter scale of the VU movement. As such no log amplifier has been included, the VU meter having a linear scale.

Since all currently available audio level meters are voltage measuring devices, if the system that receives these units is a "600 ohm" power matched system, then for the measurements to have accuracy, proper transmission line rules must be followed. That is to say, all lines must be terminated in their correct load impedance for the indicated power levels to be correct. Far preferable, however, is the conversion of all possible equipment to the voltage sourced interconnect system. See section 3.2.1. Also see the Benchmark Media Systems application note, “A Clean Audio Instillation Guide” by Allen H. Burdick.

1.2 Features of the SPM-2/3

The features of the SPM-2/3 are numerous. First and foremost is the systems ability to monitor audio in both true VU and PPM modes. An 8 dB differential is built into the meter system to accommodate the average difference between peak and average amplitudes in material that has been processed at least once. Both the CBC and ABC have arrived at this 8 dB differential independently.

Secondly the SPM-2/3 has the ability to monitor both discrete and matrix stereo. This monitoring function is instantly switchable between these two modes. This is very helpful in ascertaining correct signal polarity in a plant distributing discrete stereo. For the plant distributing matrix stereo, the meter system is invaluable for decoding, metering and aural monitoring of the sum and difference signals. Aural monitoring may be facilitated with optional balanced outputs and headphone amplifier.

Each meter has a LED peak indicator that continuously monitors the peaks of program material independently of the meter modes, be they VU or Peak, Discrete or Matrix stereo modes.

By switching to the Peak Hold mode, the Peak meter circuitry will accumulate the highest peak reading that occurs over a given time interval, until reset. This is desirable to confirm the headroom conformance of program material. This can be done even while monitoring in the VU mode.

Rear panel BNC jacks allow lissajous monitoring of the audio signals on an X-Y oscilloscope. Patch selection for these outputs may be made between the buffered inputs, matrix circuits, or the metering selector switch, which follows the meter mode selection of either discrete or matrix signals.

The following modifications exist for the SPM-2/3.

1.Pre-emphasis networks may be installed on the mother board to allow monitoring of potential transmitter over-modulation and tape saturation problems. See section 5.6 for more details.

2.Balanced outputs to feed monitor amplifiers, routing switchers or any other professional input desired.

3. Front panel stereo headphone amplifier for driving high impedance (200 ohms and above) headphones to very substantial levels.

4. Opto-isolated peak overload output from the left-sum, right-difference peak indicator LED circuits. This is useful for counting the number of audio peaks exceeding a predetermined threshold over time. This ability is ideal when setting levels into an STL, for instance.

Custom configurations, including nomenclature, are available for the meter system. Consult the factory with your specific requirements.

2.0 Unpacking

As with any delicate electronic equipment care must be exercised in the handling of the SPM-2/3 meter system. The presence of precision VU meter movements warrants extra care in this case.

If any visible shipping damage is present, notify the carrier and Benchmark Media Systems Inc.at once so that proper action can be taken.

2.1 Equipment List

The following is a list of equipment and accessories provided with the SPM systems. Check the list to assure all items have been received.

Qty	Item
1	SPM-2 Two Meter System or SPM-3 Three Meter System
2	Rack Adapters with attached screws (4)
4	#10-32 Rack Mounting Screws with plastic washers
4	Rubber Feet for desk top use
1	Installation Manual

3.0 Installation

Please use the following installation instructions for best results.

3.1 Physical Installation

The SPM-2/3 is designed to mount in a standard 19" rack, and occupies two rack units of space, that is 3.5" vertical. The SPM-2/3 is shipped without its rack mount ears installed. If you plan to mount the meter system in a 19" rack these should be installed at this time. You will note that when using the enclosed rack mount hardware you must start all four of the mounting screws into the rack rails before any of them may be tightened fully. This is because of head clearance with the mounting screws and the handles. Optional rack mount ears without handles are available. These handle-less rack mount ears are necessary if you plan to use a security cover.

As an alternative the rack mount ears may be left off and four small rubber feet installed on the bottom of the chassis for placement on a flat surface.

3.2 Electrical Installation

The SPM-2/3 comes pre-wired in the United States for 120 volt operation.

!!! WARNING !!!

> Every attempt has been made to set up the meter system for the proper line voltage for the country of destination; however before powering up the unit make sure that the transformer strapping is correct. If the system is to be installed with 220-240 volt mains, then a single strap in the center of the transformer connections must replace the two for 120 volt operation. See figure 3.2.

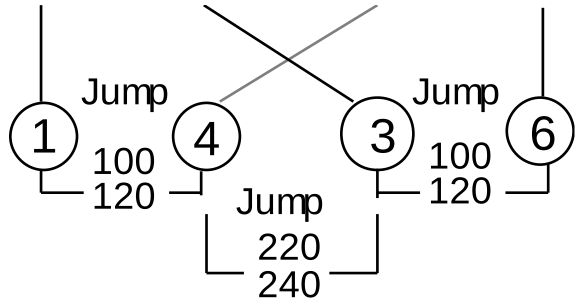

Figure 3.2 Transformer Wiring Detail

3.2.1 Measurement Conventions

The development of the voltage sourced audio interconnect system, (see "A Clean Audio Installation Guide") was brought about by the easily available low output impedance amplifier. It is generally recognized that the continued use of the term dBm (a dB ratio referenced to one milliwatt, an absolute power level with any line impedance) is not applicable to the voltage amplitudes being measured. The professional audio world is familiar with the relative voltage amplitudes that exist in the power matched systems. Additionally there are untold numbers of VU meters in operation based on those voltage amplitudes. Hence a new reference designator using the same voltage is needed. This is the dBu, where 0 dBu is equal to 0.7746 volts RMS.

!!! Warning !!!

The term dBu has no impedance or power references, and therefore may not be the most appropriate way to describe levels in sound reinforcement systems. However in most broadcast, sound recording and other systems where no gain calculations involving power in to power out are needed, it is ideal. The term dBu is found in the European Nordic N-10 standard, and is in use throughout most of Europe. In the United States as well the term is in common usage, even though there is no U.S. standard. We will use the term dBu in all of our discussions. Occasionally you may see the term dBv used in older literature from Benchmark Media Systems; this has the same meaning as dBu. Other authors may use the term dB/.7 or dB/0.775 to indicate the same voltage reference.

3.2.2 System References

There are numerous system references in use today. Those in use in professional systems are normally 0, +4, and +8 dBu or dBm systems (600 Ω origins). Most of the radio and recording systems have been setup to operate at +4, while 0 is used by those particularly concerned with system "headroom", that is the allowable increse in amplitude before clip over the average amplitude on the transmission line. Most CBS facilities use 0 dBm, 150 Ω transmission line systems. The television community generally uses +8 dBm, or +8 dBu, although many television facilities are moving to +4 and even 0 dBu system references with the transition to stereo and the new concern for audio quality. -10 dBV (-7.78 dBu) system references are used with single ended IHF type equipment, however in the professional environment this interconnect system should not be used. See "A Clean Audio Installation Guide".

3.2.3 Signal Connections

Signal inputs are made through the barrier strip on the rear panel of the SPM-2/3. When using discrete stereo inputs the nomenclature is self-explanatory. When using matrix stereo the sum signal should be placed on the left input terminals while the difference signal should be placed on the right input.

!!! Warning !!!

> If audio is brought into the meter system as a single ended signal, the unused input must be grounded for proper calibration to occur.

If you have an SPM-3 the input to the third meter is labeled "2nd Audio" at the barrier strip. This normally has the same calibration as the first two meters. Occasionally it may be desired that the third meter continuously monitor the mono sum. This is accomplished with an internal patch and gain modification of the RPM-1 board that is mounted on the third meter. See section 5.1.

If you ordered the meter system with the optional balanced outputs, they are available at the TRS 1/4" jacks on the rear panel. These are "stereo" jacks and require a Tip Ring Sleeve plug only.

!!! Warning !!!

> It is imperative that a TRS plug be used at the output of the balanced driver even if an unbalanced drive is to be used. If a Tip Sleeve plug is used, one of the two operational amplifiers will have a direct short across its output. This will cause that amplifier to clip and have severe distortion which may be reflected into other circuitry.

For unbalanced output operation, connect the unbalanced cable to the TRS plug by soldering the shield to the sleeve, the unbalanced output to the tip and leave the ring with nothing attached to it.

3.2.4 Line Up Tones

If the SPM-2/3 has been set up for a system reference level other than your house standard, you will need to re-calibrate all three meters for your house reference. Both VU and Peak settings must be calibrated. This is easily accomplished by using a stable signal generator (1 kHz is recommended) with less than 1% THD, and a precision digital voltmeter, such as the Fluke 8050A, as a measurement reference. The Fluke is especially recommended since it has an internal conversion from AC volts to dBm at various impedances. To ensure that the proper level is being fed to the meter system, 600 Ω should be selected and the meter set to the lowest scale that does not overload.

It is very useful to have a cable that feeds all of the meter inputs on the system at once rather than changing a single cable from input to input. Calibration of the VU mode must be made at the house reference, whereas calibration of the Peak mode must be done at a level that is 8 dB higher than the house reference. I.e. if the house reference is +4 dBu, this level should be fed to the system for VU calibration. +12 dBu is the correct input level for calibrating the peak circuits.

3.2.5 Calibration

The SPM-2 and -3 have two and three dip switches respectively on their boards which allow basic system calibration to the three most common system references, 0, +4 and +8 dBu. Fine calibration in both the VU and PPM modes must be performed after the basic range has been selected on the DIP switch.

The correct switch positions for the system references are:

1. 0 dBu - all switches must be turned on;

2. +8 dBu - all switches must be turned off;

3. +4 dBu - switches positions 1 and 4 must be off while switch positions 2 and 3 must be on.

The DIP switches that govern the two stereo meters are on the mother board. The DIP switch that sets the calibration of the third meter in the SPM-3 is on the RPM-1 meter board attached to the third meter. The fine calibration potentiometers for both the VU and the Peak modes are shown in the parts placement diagram, drawing number 250004. They are R2505, Left, and R3505, Right, for VU mode calibration. Potentiometers R2504, Left, and R3504, Right, are the Peak mode calibration devices. The calibration potentiometer locations for the RPM-1 meter board are also shown in the same parts placement diagram. The VU calibration potentiometer is VR2 while the Peak mode calibration potentiometer is VR3.

The Peak LED indicator calibration was set at the factory to trip at a threshold of +20 dBu unless otherwise requested. Since the input clip point for most equipment of modern design is +27 dBu, this allows a safety margin of approximately 7 dB. Once again the location of the LED peak indicator calibration potentiometers are shown in the parts placement diagrams. The Left channel peak LED calibration potentiometer is R2404 and the Right channel potentiometer is R3404. VR1 is the peak LED calibration potentiometer for the RPM-1 board. The approximate range of the Peak LED calibration potentiometers is +16 to +26 dBu.

3.3 Internal Patch Points

Part of the versatility of the SPM-2/3 meter system is found in the ability to pick various internal patch points as sources for the scope feeds, optional balanced outputs, and a headphone amplifier. There are three sets (that is, stereo) of pickoff points in the SPM-2/3 system for use as sources. The first set is the buffered inputs. The second pickoff point is the output of the matrix stereo de-code/encode circuits. The third pick-off point is the output of the CMOS analog switch that is used to choose between the input buffers or the matrix circuits. The signals that are monitored at the buffered inputs and the matrix outputs may be either encoded matrix stereo or decoded discrete stereo, dependent on what is coming into the system. If discrete stereo signals are fed to the meter system, then the output of the matrix circuits are indeed sum and difference signals. If, however, the system input signals are sum and difference, then the output of the matrix circuits are discrete left and right.

Most often the source for the balanced outputs will be the point at which discrete stereo is found, be this the input buffers (normally) or the output of the matrix circuits, when decoding. The headphone amplifier and the scope feeds however, will give the most information to the technician when sourced from the switching circuits, since both discrete and matrix stereo may be monitored.

The location of the various patch points is along the rear of the printed circuit as shown in the parts placement diagram.

3.4 Installation of Accessories

Current shipment of the SPM-2/3 chassis have all rear panel accessory mounting holes pre-punched with the exception of the aux connector, with Lexan® covering the openings. Scope outputs, originally an option, no longer are. If your SPM-2/3 was shipped without scope outputs the hardware for the same may be obtained from the factory without charge; however you will be responsible for creating the mounting holes and installation. With the current board layout only three auxiliary circuits may be powered by the main board. If you own an SPM-3, one of the three power header pin sets has been used to drive the RPM-1 board for the third meter. This leaves powering for either two balanced outputs or one headphone amplifier. As an alternative, the power supply wires from one of the balanced outputs may be soldered to the bottom of the other board, leaving the third power pin set for an HPA-1 stereo headphone amplifier.

3.4.1 HPA-1 Headphone Amplifiers

The Benchmark stereo headphone amplifier, the HPA-1 may be mounted in the front panel of the chassis at any desired location. The installation requires two mounting holes; one 5/16" diameter hole for the stereo volume control and one 3/8" hole for the headphone jack. Center to center distance between the holes should not exceed 3". Caution should be used when tightening the two mounting nuts so as not to twist the interconnecting wires or strip the plastic threads on the headphone jack.

Power and signal connections are required. The power connections are made via a three pin Molex SL connector to one of the three pin groups (auxiliary regulated D.C. power) at the rear of the power supply area. The wire color code used at Benchmark is: red = + voltage; blue = - voltage; and black = ground (signal reference). See the HPA-1 manual for its connector information. Only signal lines need be run to the HPA-1; signal grounds are brought in through the analog reference for the power supply.

!!! Warning !!!

> Due to current limitations at the power supply of the SPM-2/3 only high impedance headphones in the 200Ω to 600Ω range, or higher, may be used with the meter system.

3.4.2 Balanced Output Amplifiers

The balanced output amplifiers that would normally be used for the SPM-2/3 are DOA-1s. These are D.C. coupled devices that use bipolar power as provided by the meter system. These units should be ordered with 1/4" TRS jacks for easy mounting in the meter system chassis. Again the signal source can be one of three possibilities, - the buffered inputs, the matrix circuits or the analog switch. As with all accessories, power is taken from the auxiliary power interface. Only signal lines need be run to the DOA-1s, signal grounds are brought in as the analog reference of the power supply.

3.4.3 Oscilloscope Outputs

The discrete Left and Right signals will always appear at one of the three patch points, depending upon the type of signal feeding the system. Scope feeds may be taken from this discrete output, or they may be taken from the switched output of the meter system, which is out preferred option.

Since the BNC connectors that feed the oscilloscope are of the floating variety, both the signal ground and the signal line itself must be connected to the meter signal outputs at the rear edge of the printed circuit assembly.

!!! Warning !!!

It is very easy to invert the polarity of the Molex SL connector at the signal outputs. While no permanent damage will occur, to do so will short the output of an operational amplifier and make the meter system appear inoperative.

4.0 Theory of Operation and Repair

The meter system consists of a number of relatively simple functional circuits. As such the signal flow is easy to follow. It is well to read this circuit description with a schematic, document number 450017, and component assembly, document number 250004, at hand.

4.1 Circuit Board De-Soldering

Printed circuit boards are <u>very</u> easy to damage by excessive heat. Unless you have developed the specialized skills necessary to remove and replace components, we suggest that you leave the task to someone skilled in these techniques.

When servicing printed circuit boards we strongly recommend the use of a vacuum de-soldering station, such as the Pace MBT-100. The proper technique with these stations is to apply the tip to the area to be de-soldered and wait for the solder to thoroughly melt. You can be sure of a thorough melt by observing the top side of the board. <u>When</u> the solder there has become liquid, apply the vacuum while moving the hollow tip with the component lead in a circular motion. By rotating the lead, with the tip against the board, but <u>without</u> applying pressure to the pad, you are able to most thoroughly remove solder in the plated-through hole. In turn the component will often drop out of the board when you are finished. If the solder is not thoroughly removed from the plated-through hole, attempting to remove the component will bring with it plating from inside the hole. This may destroy the usefulness of the board. If you find that your attempt to completely remove the solder from the hole and pads has failed, do not attempt to re-heat the area with the de-soldering tool, as this will <u>overheat</u> the pad, and not the area that is in need. As a result the board is usually damaged. Rather, re-solder the joint, and then go back and apply the proper technique, by allowing the solder in the joint to thoroughly melt <u>before</u> applying vacuum. This technique uses new solder as an efficient heat conductor to the total area, eliminating hot spots.

4.2 Circuit Board Re-Soldering

NASA has developed an effective technique that ensures highly reliable solder joints. It involves first heating the component lead, since it usually has the higher mass, by applying a small amount of solder to the tip of the soldering iron at almost the same time as you apply the iron to the component lead. This will allow some flux to make it to the component lead. The iron should be approximately 1/8" above the board. When the lead has come up to temperature so that it melts the solder when placed against it and has good wetting, slide the soldering iron down the lead and heat the printed circuit board pad while applying a controlled amount of solder to the joint. All of this should take no more than a couple of seconds. If the component that is to be installed has leads that are oxidized, it will be necessary to clean them. This may be done with either a Scotch Bright® abrasive pad or fine bristle fiberglass brush, among other methods.

4.3 Input Circuits

The input circuits,U2101A (U3101A), are highly trimmed differential amplifiers. The choice of a trimmed input was made because audio, on some occasions, will pass through the meter system and will be fed to other points. The input impedance is 100 kΩ differential and 50 kΩ single ended. The circuits have been trimmed at the factory for ≈ 90 dB common mode rejection at 2 kHz and ≈ 75 dB rejection at 20 kHz. Up to 20 dB degradation of these figures can be expected under temperature extremes. Common mode trims are passive trims; that is they affect only the balance of the resistor - capacitor bridge around the operational amplifier. As such, once properly adjusted they should never need readjusting, even when replacing a defective operational amplifier. The only exception to this would be components that were damaged from excessive inputs (lightning or equivalent). A six dB loss is taken at the input to maximize headroom. The circuits are designed to roll off at 320 kHz by use of the capacitive feedback compensation. The outputs of these input amplifier circuits are brought to the back of the board as option tie points to feed the scope outputs, the optional balanced outputs, or the optional headphone output.

4.4 Matrix Circuits

The matrix circuits consist of standard sum and difference circuits, U2101 and U3101 respectively. The summing amplifier uses matched resistors to achieve, typically, a 50 dB null across the audio band. No trims are used in the summing circuit. The difference circuit is similar to the input amplifier, with the exception that no loss is typically taken at this point. The differential circuit is used for optimum L-R operation. Typically 90 dB of rejection is achieved through 1 kHz with a degradation to ≈ 60 dB at 20 kHz. These circuits have been trimmed to this level of performance, keeping in mind their potential encoder/decoder use in the audio chain. Again, the outputs of the matrix circuits are brought to the back of the board as option tie points for output to the various user selectable destinations.

4.5 Matrix Headroom Considerations

A potential problem exists in the matrix section of the SPM-2/3 as it does in any encode or decode equipment. By looking at the algebra involved, it is easy to see that with amplifiers operating at unity gain, every time the signal goes through the encode - decode process a 6 dB voltage gain occurs simply as a result of the process. See equation 4.1a and b.

$$(L+R) + (L-R) = 2L \qquad [4.1a]$$

$$(L+R) - (L-R) = 2R \qquad [4.1b]$$

These voltage gains directly reduce the headroom of the encoders and decoders as well as upset the levels that may be exported from the meter system to the rest of the audio environment. If the signals that come into the SPM-2/3 are above the normal system references or if the material is extremely percussive, internal clipping may occur. Also if there is significant common material between discrete left and right inputs then up to a 6 dB voltage addition takes place in the summing amplifier. This needs to be considered if the output of the matrix circuits are selected for export to the rest of the house audio system. Probably the best alternative, the one we recommend, is to take a 3 dB loss in the sum and difference amplifiers of both the encoder and the decoder. This means that only 3 dB, instead of 6 dB, of headroom is given up for totally correlated material in an encoder summing amp. Additionally, with both encoder and the decoder having a 3 dB loss, there will be no net amplitude gain or loss as a result of the encode-decode process.

With all of this said, we at Benchmark still have a problem. We do not know how the manufacturer of your stereo generator has handled the above stated problems. If “they” have taken a 3 dB loss as we do with our MTX-02 Stereo Control daughter board, an accessory to the Benchmark System 1000 modules, then a similar 3 dB loss should be taken in the sum and difference circuits of the SPM-2/3. But since this is still an unknown, we have elected to leave the sum and difference circuits in the SPM-2/3 at unity gain. If you desire a 3 dB loss in the sum and difference circuits it can be ordered initially as such from the factory, or you can change the feedback resistors in these circuits yourself. The former is far more preferable since the difference amplifier requires precision matching of the feedback resistors, and then a precise L-R null to be performed after the resistors have been changed. Please contact the factory for the necessary parts if you decide to make this change yourself.

4.6 Audio Switching Circuits

The outputs of the input buffers and sum and difference circuits are brought to the switching circuits. The switch consists of U2201 (U3201), a 4066 CMOS analog gate that is arranged in a series-shunt current switch configuration. U2202A (U3202A) is the output amplifier for the FET switching. The analog switch is placed at the summing node of the operational amplifier. The series-shunt arrangement eases the voltage stress on the FET switch, lowers the distortion caused by the FETs, provides a high degree of crosstalk isolation at high frequencies, and allows the CMOS package to be operated between the +15 volt supply and ground. The analog gate is driven directly by the output of the CMOS bi-stable latch.

4.7 Network Insert Point

A “gain-pre-emphasis” option exists on the main circuit board. As the name implies, optional networks may be inserted at this point to allow for switched “0” references and numerous pre-emphasis time constants. These will be discussed in detail in section 5.0, “Custom Modifications”. The normal wiring of this section ties the non-inverting input, pin 5, to ground and uses input resistor R2301 (R3301) and feedback resistor R2303 (R3303), which are 24.9 kΩ 1% metal film resistors. Additionally the 18 pF feedback capacitor rolls off the amplifier at 320 kHz.

4.8 Full Wave Rectifier-Peak Detector

In this circuit block two basic functions have been combined, eliminating one op-amp that would have otherwise been needed. The first function is that of full wave rectification. The signal at this point splits and takes two paths (in addition to the VU meter path). The first is through op-amp U2301A (U3301A). This is a half wave rectifier (negative half cycle output). The second path is around the half wave rectifier where it sums with the rectifier’s output. By summing and structuring the gain of these two signals, that is, the original AC and the half wave rectified AC, full wave rectification is performed. The gain of the half wave signal is twice that of the original AC signal at the summing amplifier. This is accomplished by the ratio of resistors R2303 (R3303) and R2304 (R3304) to the feedback resistor R2307 (R3307).

In addition to summing the two signals, U2301 (U3301) acts as the first stage of a peak detector.The output of the device is a positive going pulse that turns on Q2401 (Q3401) through diode D2401 (D3401) providing the drive current to charge capacitor C2401 (C3401). The limitation to the time that is necessary to charge this capacitor is set by resistor R2403 (R3403). The value of this resistor has been chosen to conform to the standard IEC 10 ms integration time to -1 dB of final value. The transistor continues to pump current into the capacitor until the voltage at the capacitor, monitored by the non-inverting buffer amplifier, reaches the input voltage as delivered by the full wave rectifier. At this point the op-amp turns off and the diode in series with the transistor becomes reversed biased. The emitter and the base of the transistor, however, are held at the same voltage as found across the capacitor by the 1 MΩ resistor R2401 (R3401). This reduces leakage currents through the transistor, which is inherently a very low leakage “diode”. Leakage currents through the reverse biased diode 1N4148 are provided for by the 1 MΩ resistor. This scheme lowers the number of potential leakage paths around the holding capacitor, which in turn allows a long holding time when in the peak hold mode. With the input bias current of the buffer amplifier at approximately 30 pico amps, which is the predominant leakage path if the printed circuit board is extremely clean, the droop for this circuit is 1 dB in five minutes minimum, and will often be 1 dB in 20 minutes. It is important to remember that if any work is done on the printed circuit assembly in this circuit area, the board must be cleaned exceptionally well to maintain this standard of performance.

4.9 Time Constants

The Time constants chosen for the SPM-2/3 meter system conform to the IEC 268-10 (DIN 45 406, Nov 1966) specification, as previously mentioned. Basically they provide for an integration time of 10 ms, where the meter comes up to within 1 dB of the final value when impressed with a 10 ms burst of 5 kHz sinusoidal tone, and within 4 dB with a 3 ms burst. The fall time is 1.5 seconds for a drop of 20 dB. The spec also provides for a meter lag of less than 300 ms. In this case "meter lag" does not mean peak to average ratio, but rather the meter movement's response time to the electronic signal. The standard VU meter has an integration time of 300 ms and hence comes very close to that specification.

4.10 Switch Control Circuits

The switch control circuits are bi-stable CMOS latches, consisting of a pair of standard inverters with feedback. A momentary pushbutton switch alternates the state of the latch. The switch uses the charge on the 0.047 µF capacitor, (C4101 etc), to temporarily overpower the feedback voltage, via the 4.7 kΩ resistor (R4501 etc), to the first inverter with a voltage of the opposite state. The outputs of the inverters drive the FET analog gates directly, and also feed the LED driver transistors to indicate the state of the logic. The three latches use two inverters each, thus all six inverters in one 4069 package are used.

4.11 Calibration and Switching Circuits

The output of both the gain/pre-emphasis option amplifier and the peak detector are brought to the input of the meter driver amplifier through FET switches and calibration networks. Calibration takes place in both circuits by simply changing the input resistance to the amplifier and thus changing the gain of the inverting amplifier. Both legs of these input strings have one non-switched fixed resistor and two fixed resistors that may be switched out of the string. Additionally variable fine trim potentiometers allow very close calibration of each mode of operation. The two switches in each leg provide for the three most common system references of 0, +4, and +8 dBu. The output of these resistor strings feed two FET switches. The FET switch that carries the AC signal for true VU operation is a series-shunt configuration, the same as in the earlier stages. The output of the peak detector feeds a simple series switch; since no high frequency information is present, crosstalk will not occur in the off state. Also since the DC present is a positive voltage it may be handled by the analog gate. This leaves the fourth analog gate in the quad package for the Peak Hold function. It also handles only a positive voltage, and is the switch that turns off the discharge path for the holding capacitor, the decay time circuit.

4.12 Meter Driver

The meter driver amplifiers handle both an AC and a DC output. This circuit uses the copper oxide rectifier within the VU meter to establish the correct polarity of the DC signal in the PPM mode. The 3.9 kΩ resistor establishes the correct damping and calibration of the VU meter. In a "600 Ω" power matched system the build out resistor would be 3600 Ω, but because we do not have the 300 Ω equivalent source impedance of the "600 Ω" line (the output impedance of the operational amplifier is essentially 0 Ω) the additional resistance must be added.

4.13 Meters

The true VU meters are custom manufactured by Sifam, a British company. The meters are of a very high quality. They include illumination, with two 12 volt lamps. The lamps are wired in parallel inside the meter and then in series between the meters. The lamps are fed AC from the secondary of the power transformer.

4.14 LED Peak Indicators

As an operational feature the SPM-2/3 meter systems have peak indicators that are in constant operation, whether the meter system is in the Peak or VU mode of operation. The peak indicator LEDs are mounted in the face of the meter and the circuit can be adjusted to trip within the range of approximately +16 to +26 dBu. They are adjusted at the factory to trip at +20 dBu unless otherwise specified.

The peak indicator circuit uses an op-amp as an oscillating comparator by using positive AC coupled feedback. Initially the output voltage of the comparator is near the + supply voltage, the off state. The comparator is held in the off state by the bias that is applied to the inverting input until an input voltage overcomes the preset bias. At that point the comparator trips. The trip point is determined by the resistor string R2404 (R3404), R2405 (R3405), and R2501 (R3501). R2404 (R3404) is the calibration trim for the peak indicator. When the comparator trips the output voltage swings to the opposite supply rail. The 0.1 µF capacitor, in turn, pulls the noninverting input negative holding the comparator in the on state. The capacitor recharges with opposite polarity through the two 220 kΩ resistors and when the threshold is passed (assuming the audio peak has gone) the device turns off. It is now held off, again by the charge on the capacitor.until the capacitor recharges to its original state. The circuit acts as a pulse stretcher, allowing the operator to "see" very short peaks as they occur. Occasionally, when using a system reference of +8 dBu, the peak LED indicator will flash even though the meter itself may have only reached +19 dBu indication. This is because of the mechanical meter lag of the movement (≈300 ms).

Since this circuit monitors the peak detector circuit, it is always in operation. If however the meter system is placed in the Peak Hold mode it is possible for a peak to activate the LED indicator and then remain in the on state since the input voltage to the circuit remains high.

4.15 Power Supply

The power supply uses a Signal Transformer model # 14A-10-36 transformer. This is a 10 VA device capable of 280 mA at 36V AC. The input of the transformer is strappable for 120 - 240 volt operation. See section 3.2. With the center tap of the transformer grounded, a bipolar supply is created. The center tap of the transformer is grounded, creating the bipolar aspect of the supply. Individual 3300 µF filter capacitors C4901 and C4801, and integrated circuit voltage regulators U2701, an LM317 positive regulator, and U4701, an LM337 negative regulator, comprise the basic control section of the power supply. The output voltage of the regulators is set by the ratio of resistors R3703 (R3704) and R3701 (R3704). This ratio yields an output voltage of 15 volts positive and negative. Capacitors C3701 and C3702 reduce the amount of ripple and noise at the output of the regulator. Diodes D3701 and D3704 provide protection to the regulator from the two previous capacitors. Capacitors C2601 and C3601 stabilize the output of the regulators.

4.16 RPM-1 Board

The RPM-1 board is a single channel driver for the third meter in an SPM-3. The board is very similar in operation to the main board, with the exception of the matrix circuits and the logic control. Additionally the RPM-1 has a low pass filter after the input stage, which may be removed and replaced with gain or pre-emphasis options. A more complete description of the RPM-1 is given in the accompanying RPM-1 manual.

The RPM-1 board in the SPM-3 is a "stripped down" version of the normal RPM-1 in that it does not have LED status indicator drivers, or gang switch drive transistors. The +12 volt regulator has been eliminated and the logic circuits operate on +15 volts as on the main board. See schematic #25xxxx.

4.17 RPM-1 Interconnection
The RPM-1 board on the third "second audio" meter, obtains power and logic inputs from the main board. Bipolar 15 volts comes from the Aux DC power headers, while the logic connects to the main board via a five wire "pigtail" to header pins 58 through 65. The logic drive from the main board for VU and Peak, Peak Release, and Peak Hold interface at the RPM-1 with the respective gate inputs of the 4011 quad dual input NAND gate. Each of the respective inputs are held low when that function has been selected. The four wires, yellow, blue, violet, and gray, connect where the collectors of the gang switch transistors previously would have connected.

5.0 Custom Modifications
As with all Benchmark products, versatility is a prime design requisite. The following modifications may be made by the user to the standard SPM-2/3 meter system or ordered directly from the factory, making this one of the most versatile metering systems available.

5.1 Continuous Mono Metering
Since both the left and right inputs of the system are summed in the matrix circuits, continuous MONO metering may be easily accomplished by an internal signal patch and re-calibration of the the third meter by changing the feedback of the input stage.

The signal patch ties the input of the third meters card, the RPM-1, to the output of the summing amplifier at the header pins 14 and 15. One end of the patch cable must be connected to the input of the RPM-1 board, while the other end must be connected to pins 14 and 15. Pin 14 is the signal connection while pin 15 is ground. The polarity at the input to the RPM-1 is unimportant. This is an unbalanced signal and is 6 dB lower than the left and right inputs. Once again the gain of the summing circuit should be considered, see section 4.5. The input circuit of the RPM-1 will need to be changed from its normal 12 dB loss to a 6 dB loss. The change replaces the two feedback resistors on the input circuit for the proper gain structure. A six dB loss will require the insertion of 24.9 kΩ resistors. A slight trim of the calibration potentiometers on the RPM-1 may be necessary after this modification to make the sum matrix metering agree with the third meter. The signal strap plus two new feedback resistors for the RPM-1 are available from Benchmark Media Systems at a nominal charge.

5.2 Time Constants
Occasionally it may be desired to use time constants that are different from those shipped with the meter system such as the CCITT Max Amplitude 5 ms integration time, or the EBU Standard Program fall time of 2.8 sec for a 24 dB drop. These changes may be easily incorporated in the meter system. Change R2401 (R3401) on the main board and R33 on the RPM-1 board to modify the integration or attack time. In the case of the CCITT 5 ms integration time, the resistor value would be one half of the 10 ms standard value or 1.1 kΩ.

Fall-back or decay time may be changed by replacing R2402 (R3402) on the main board and R30 on the RPM-1 board. To calculate the correct discharge resistor for various fall times, the classical transient equation [1.] for simple RC networks is employed.

$$v = V_0 \times e^{-\frac{t}{RC}} \qquad [5.1]$$

Where:

v = the final voltage,

V_0 = initial voltage,

e = Napierian log base,

t = time to reach the final voltage,

RC = the desired discharge time constant in seconds,

and in this case C = 1 μF.

Rewriting equation 5.1,

$$R = -\frac{\left(\frac{t}{\ln [v/V_0]}\right)}{C} \quad [5.2]$$

Since v/V_0 is the voltage fraction defined by the desired dB drop, we first solve for this fraction, then insert the known time, and the known C to solve for R.

For an example let's use the EBU case of -24 dB in 2.8 seconds:

For a 24 dB drop the v/V_0 ratio is: $$-24 = 20 \text{ Log} \frac{v}{V_0}, \quad [5.3]$$

therefore; $$\frac{v}{V_0} = 10^{-1.2} = 0.063$$

and from 5.2 $$R = -\frac{\left(\frac{2.8}{\ln 0.063}\right)}{1 \times 10^{-6}} \quad [5.4]$$

$$R = 1.012 \text{ M}\Omega$$

5.3 -10 dBV Calibration

The IHF interconnect system uses a voltage amplitude of -10 dBV for signal interchange. This is the equivalent to a voltage amplitude of -7.78 dBu. The term dBV uses a voltage reference of 1.000 volts. When monitoring the amplitudes of signals that use this standard, such as in mass tape duplication facilities, it is necessary to alter the sensitivity of the SPM-2/3 meter system. This may be done by adding 8 dB of gain to the gain/option stage of the SPM-2/3s main board as well as 8 dB to the input stage of the RPM-1, and then calibrating the system as though it were receiving a 0 dBu signal. The correct 1% metal film input resistor R2301 (R3301) value for the main board is 10 kΩ . 31.6 kΩ resistors should replace the 12.4 kΩ feedback resistors on the RPM-1. Please note these feedback resistors are matched to within 0.1% when assembled at the factory, and this is desirable in the field as well.

5.4 Switched Level Metering

Changing the sensitivity of the meter system, as we have just seen,.is among the various options of the SPM-2/3 This may be a fixed permanent change, as with the -10 dBV modification above, or a switch may be used to select various gain arraignments. A Centralab subminiature ceramic rotary switch (model number PS-103) may be used to select between eleven sets of resistors, yielding 11 sensitivities for the two channels. To perform this modification, we will continue to use the inverting amplifier configuration at the "gain / pre-emphasis" option point, as shipped, and the 24.9 kΩ feedback resistors. We will replace the input resistor to the stage R2301 (R3301) with the switch assembly that allows the 11 different input resistors.

Wire one leg of the resistors to each of the positions of the switch. Buss the opposite legs of the resistors together. Runs wires from the bussed legs and the pole of that section to the pads where the original R2301 (R3301) resistor resided. If you prefer you may choose to use standard values of 1% resistors that are one step lower than the recommended standard value and then insert a trim resistor in series with each fixed resistor for perfect calibration at each sensitivity setting. The following table gives recommended resistor values for many of the most commonly needed sensitivities. Once the resistor-switch network has replaced the input resistor R2301 (R3301) the unit must be switched to the new 0 dBu position and then the meter system must be calibrated for a 0 dBu house reference. This does not mean that your house reference must be 0 dBu, but simply that the meter must be calibrated for that reference with this modification. See section 3.2.4 Please note that with a 8 dB peak to average ratio normally expected and built into the gain structure of the meter system, and since the input clip point of the meter inputs is +27 dBu, the last "0" calibration point is only usable with tone, and then when fed to only one channel. In fact the + 18 dBu cal position will probably clip, in the summing amplifier if nowhere else, with percussive program material. This is usually of little consequence to the quality of your program audio (except that metering accuracy is lost) since the metering circuitry is isolated from the the program line resistively and this option will probably never be used with the balanced output option.

"0" Calibration	Stage Gain	R_i Calculated	Standard 1%	Gain Error
-24 dBu	+24 dB	1.571 kΩ	1.58 kΩ	-0.05 dB
-18 dBu	+18 dB	3.135 kΩ	3.16 kΩ	-0.07 dB
-12 dBu	+12 dB	6.225 kΩ	6.19 kΩ	+0.09 dB
-8 dBu, -10 dBV	+8 dB	9.913 kΩ	10.0 kΩ	-0.08 dB
-4 dBu	+4 dB	15.711 kΩ	15.8 kΩ	-0.05 dB
0 dBu (Cal Pos)	0 dB	24.900 kΩ	24.9 kΩ	0.00 dB
+4 dBu	-4 dB	39.464 kΩ	39.2 kΩ	+0.06 dB
+8 dBu	-8 dB	62.546 kΩ	61.9 kΩ	+0.09 dB
+12 dBu	-12 dB	99.129 kΩ	100.0 kΩ	-0.08 dB
+18 dBu	-18 dB	197.788 kΩ	196.0 kΩ	+0.08 dB
+24 dBu	-24 dB	396.638 kΩ	392.0 kΩ	+0.06 dB

Table 5.1 Variable Gain Resistor Selection

5.5 150 Ω Operation

The SPM-2/3 meter system may be easily modified for operation with "0 dBm" operation across 150 ohm lines. This is simply a matter of changing resistor R2301 (R3301) from its value of 24.9 kΩ to 12.4 kΩ. This modification raises the gain of the "gain / pre-emphasis" amplifier to 6 dB from unity, the amount necessary for the voltage difference between 150 Ω and 600 Ω transmission line systems. Once this is accomplished, the meter system must be re-calibrated for a new system reference of "0" dBm (0.3873 volts) using the 0 dBu switch calibration positions. See section 3.2.4. If you have an SPM-3 and want the third meter to have the corresponding increase in amplification, remove the 12.4 kΩ feedback resistors, R4 and R5, from the input stage of the RPM-1 board and replace them with 24.9 kΩ matched resistors. This gives a corresponding 6 dB sensitivity increase to this input. Once again the meter will have to be re-calibrated for the new "0" dBm house reference (0.3873 volts) using the 0 dBu switch positions. See section 3.2.4 of this manual and the modification section of the RPM-1 manual.

5.6 Pre-emphasis Networks

The ability to add pre-emphasis networks to the SPM-2/3 is one of its most powerful features. With pre-emphasis networks it is possible to "see" the effect of the program material on the headroom of tape recorders, some noise reduction systems and the modulation of transmitters. Additionally the LED peak indicator may be set to trip at the equivalent of 100% modulation or tape saturation.

Using the optional opto-isolator output, for instance, you may count the number of times over modulation occurs in any given time interval. This system, of course, is not a true modulation monitor, and as such does not account for effects such as ringing in sharp cutoff filters. But as a modulation meter, it is very useful to monitor audio levels that feed STL links which do not have limiters on their inputs. The following chart gives the component values for various popular time constants.

T.C.	f1	R2203	C2301	R2302	C2202	Max A	J1	f2	f3
25 µsec	6.37 kHz	24.9 kΩ	0.001 µF	3.92 kΩ	100 pF	17.33 dB	a-b	40.6 kHz	63.9 kHz
50 µsec	3.19 kHz	49.9 kΩ	0.001 µF	3.92 kΩ	56 pF	22.75 dB	a-b	40.6 kHz	57.0 kHz
70 µsec	2.27 kHz	31.6 kΩ	0.0022µF	1.64 kΩ	82 pF	26.14 dB	a-b	44.1 kHz	61.4 kHz

75 µsec	2.12 kHz	34.0 kΩ	0.0022µF	1.64 kΩ	82 pF	26.14 dB	a-b	44.1 kHz	57.1 kHz
90 µsec	1.77 kHz	41.2 kΩ	0.0022µF	1.64 kΩ	68 pF	28.34 dB	a-b	44.1 kHz	56.8 kHz
120 µsec	1.33 kHz	54.9 kΩ	0.0022µF	1.64 kΩ	47 pF	30.75 dB	a-b	44.1 kHz	61.7 kHz

Table 5.2 Pre-emphasis Network Values

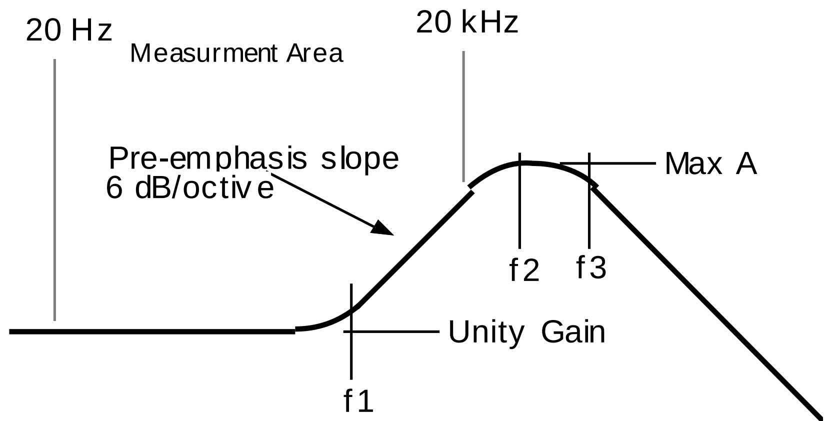

Fig 5.1 Pre-emphasis Curve

Figure 5.7 shows the various break point frequencies of the pre-emphasis gain structure. f1, the main break point of the network, is set by the resistor – capacitor combination R2203 (R3203) and C2301 (C3301). R times C yields the desired time constant; therefore, if we choose a value of capacitor, such as 0.001 µF, the correct companion resistor is easily determined. The pre-emphasis network would work with only the f1 components. However the amplification of this stage would continue to rise versus frequency unabated. This would push the op amp to an open loop condition at some high frequency. This is very undesirable for noise performance and RF stability. We therefore include R2302 (R3302) to limit the gain increase to a fixed gain (Max A) at frequency f2, approximately 40 kHz. This frequency is set by the R-C combination R2302 (R3302) and C2301 (C3301). f3 is the break point for the roll off necessary for RF stability. In the above calculations for the various break points, "f" is determined by:

$$f = \frac{1}{2 \pi R C} \qquad [5.5a]$$

And conversely "R" is determined by:

$$R = \frac{1}{2 \pi f C} \qquad [5.5b]$$

Figure 5.2 is an exploded view of the parts placement on the main circuit board. To install the pre-emphasis option you must remove both R2301 (R3301) and jumper J1 (a-c). New values from the table must be installed in positions R2203 (R3203) and C2202 (C3202). Also totally new parts must be installed in positions R2302 (R3302) and C2301 (C3301). It is well to purchase a quantity of the film capacitors and select the values that are closest to the specified C2301 value. Care must be exercised when working on the printed circuit assembly or damage to the board may result. See section 4.1 and 4.2.

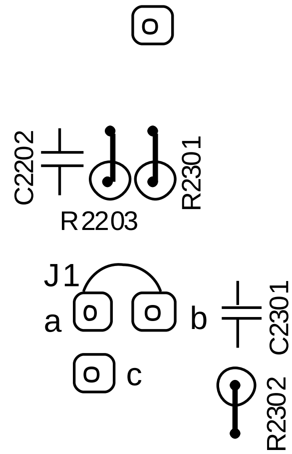

Figure 5.2 Circuit Board Detail

5.7 Opto Isolator P/OL Output
Each of the peak indicator LEDs on the main board has provision for a series connected LED opto isolator. The opto isolator will provide a totally isolated (from the meter system) pulse that may be used to count the number of times a channel exceeds the pre-set trip amplitude. This level can correspond to 100% modulation of a transmitter, the saturation of an analog tape recorder, or even hard clip. The ability to count the overmodulation occurrences is very helpful when setting up a studio to transmitter link if no safety limiter has been included in the air chain. This is most commonly found at classical music stations. Additionally the pulses may be integrated and used to control a long time constant AGC circuit if desired.

The meter system as normally shipped, does not have an opto isolator in its intended socket. Instead, a jumper has been inserted in place of the series LED. This must be replaced with the 4N33. The 4N33 is a six pin device and its socket is eight pin. Therefore, it is possible to insert the opto-isolator into the socket incorrectly. The correct position for the opto-isolator is to use the “upper” pins, that is pins 1-3 and 6-8. Pins 4 and 5 should remain empty. Additionally, a connector is required at the rear of the chassis to output the collectors and emitters of the photo transistors. We recommend a four or six pin DIN connector for ease of installation. The connector should be installed at the aux connector location. (A six pin connector will allow both isolated ground and +12 volts to be brought out of the chassis as well. This may be used in the creation of the pulse network where separate power in not needed.) Figure 5.3 gives the recommended network using the internal power from the SPM-2/3.

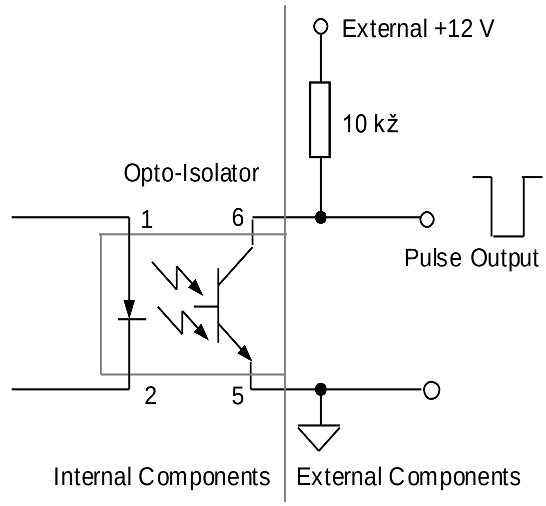

Figure 5.3 Opto-Isolator Pulse Network

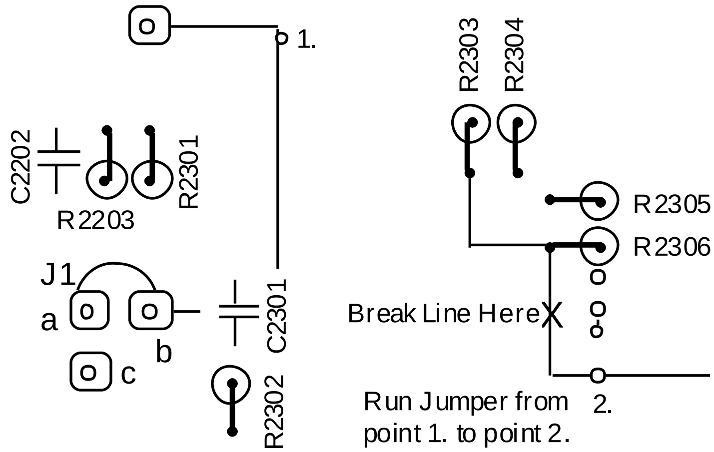

Figure 5.4 Pre Pre-emphasis Board Modification

5.8 Pre Pre-emphasis VU Selection

On some occasions it may be desired to operate the VU section in a non-pre-emphasized mode and the Peak section in a pre-emphasized mode. To do this, the trace that comes from the output of U2202B (U3202B), pin 7, located on the top of the circuit board, must be cut and re-routed to the output of the "A" section (pin 1) of this integrated circuit. Figure 5.4 illustrates the proper location for this modification.

References

1. Electrical Engineering Science, Preston R. Clement and Walter C. Johnson, McGraw-Hill Book Company, Inc., 1960

This completes the SPM-2/3 manual Ed. August 18, 1988

BENCHMARK MEDIA SYSTEMS INC.
3817 Brewerton Road. North Syracuse, NY 13212
(315) 452-0400