## *BENCHMARK MEDIA SYSTEMS, INC.*

# RPM-1 Meter Card

## - Instruction Manual -

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### 1.0 History of the VU Meter

The VU meter as developed by a joint effort between NBC, CBS and Bell Telephone Laboratories in 1939, represented 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 and both networks blaming the carrier, and vice versa. The realization of Standard Volume Indicator, or S.V.I., now commonly called the "VU" meter, whose units of measure are Volume Units, or VU, was a major step forward for consistency in program interchange. The VU meter developed by Bell, and originally primarily manufactured by Weston, gives good representation of what is heard by the listener, since it has a response characteristic that is close to RMS. But since the VU meter does not read peaks of program material, an audio operator can get into trouble if enough headroom has not been designed into the system. This is because some program material has a very high crest factor. Speech and especially percussive music can have peaks that are 16 dB or higher than the indication given by the meter. For this reason, it is most desirable to have peak reading capability as well as VU indication, especially with digital recording, where we no longer have the built in compression effect of analog tape. This is the rationale behind the development of the RPM-l.

### 1.1 Meter Technicalities

The meter developed by Bell is designed to give a 0 indication when placed directly across a 600 Ω line that is dissipating 1 milliwatt of audio power. This is accomplished by the use of a 200 microamp meter movement, a full wave copper oxide, or selenium rectifier and a precision (1%) 700 Ω series resistor. The total internal impedance of the meter is 3900 Ω. When 0.7746 volts is impressed across the meter terminals, 0 is indicated. Good engineering practice, however, dictates that for a load to be bridging, it must have an impedance that is at least 10 times higher than the source. For this reason an additional 3900 Ωs was placed in series with the meter. This comes in the form of a 3600 Ω resistor and 300 Ωs of equivalent impedance from the 600 Ω line. This allows a 3900 Ω attenuator to be placed in between the 3600 Ω resistor and the meter, which in turn, allows higher levels to be measured. The inclusion of the 3600 Ω resistor results in a 4 dB loss - that is, the meter now reads -4 when placed across the 600 Ω line operating at 0 dBm. As a result, it became common for many facilities to use +4 dBm as their system reference, since it yields a zero indication on the "VU" meter. "Zero VU", by definition, is present only with program material, as determined by the designers of the meter.

This is a totally passive system, and before the days of the operational amplifier, that was very desirable. Even the 0.3% total harmonic distortion that an un-buffered meter can add to a program line was considered to be inaudible; thus, the meters development was, all in all, a major accomplishment.

### 1.2 The PPM

The peak program meter has its roots is Europe and began life in the mid 1930s. The PPM has many differing standard definitions. 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.

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.

## 1.3 The RPM-1 Combination VU and PPM

In spite of often-stated arguments between proponents of each meter system, both the VU meter and the PPM have their advantages. The VU meter correlates very closely with what is heard by the system operator, whereas the PPM shows true peaks of program material, minus the attack time constant, and thus relates to system overload better than the VU meter. Both the VU meter and the PPM have an enormous established base of user experience, the VU meter in the United States, Australia, and Japan, the PPM in Europe and elsewhere.

In the RPM-1 meter card we have chosen the VU meter as primary metering. The PPM section therefore must conform to the meter scale of the VU movement. No logarithmic amplifier has been included: the VU meter has a linear scale.

Since all available audio level meters are voltage measuring devices, and if the system that receives these units is a "600 Ω" power matched system, then, for the measurements to have accuracy in terms of power measurement, 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 more preferable, however, is the conversion of all equipment possible to the voltage sourced interconnect system. See the Benchmark Media Systems application note, "A Clean Audio Installation Guide" by Allen Burdick.

## 2.0 Measurement Conventions

The development of the voltage-sourced audio interconnect system, 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.

### !!! Notice !!!

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 and the United States as well, 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.

## 2.1 System References

There are numerous system references in use today. Professional systems normally use 0, +4, and +8 dBu or dBm systems (600 Ω origins). Most radio and recording systems have been setup to operate at +4, while 0 is preferred by those particularly concerned with system "headroom", that is the allowable increase in amplitude before clip over the average amplitude on the transmission line. Most CBS facilities use 150 Ω transmission line systems operating at 0 dBm. 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".

## 3.0 Connections to the RPM-1 Card

There are three basic system interconnections that have to be made to properly interface the RPM-1. These are; 1) audio signal in, 2)-power supply, and 3) mode control switching and indicator connections.

## 3.1 Audio Input Connections

Audio input to the meter card is provided through a 3-pin header and mating three-pin female housing located at the top left-hand corner of the circuit board. The pins are numbered sequentially beginning with the left-most pin, which is pin number one. The RPM-l has a bridging differential input with an input impedance of 100 kΩ. It has a single ended input impedance of 49.9 kΩ when operated into the inverting input (pin 3) and a 62.3 k Ω impedance when operated into the non-inverting input (pin 1). If you feed the card from an unbalanced source, and use the non-inverting input, *be sure* to ground the inverting input; otherwise, the meter calibration will be 6 dB low. The advantages of the bridging differential input are manifold. First it provides freedom from loading effects and the resultant amplitude changes across a program line. Second, it provides isolation of the VU meter rectifier from the program line and hence, the removal of the normally induced distortion. Third, it provides the ability to eliminate ground loops and other induced interference, and forth it allows direct interface to balanced outputs.

We strongly recommend that the advantage of the balanced input also be used when connecting to an unbalanced signal source. The technique needed we call forward referencing and is accomplished by first making sure that all signal references (grounds) are tied together through the use of external insulated ground wires. The drain wire of the shielded pair bringing the audio signal into the meter board should not be used for this purpose. These ground wires should be connected in a "star" configuration. The signal output is connected to the non-inverting input of the meter and then the inverting input is tied to ground at the signal *output* port. The shield (drain) wire is then tied to ground at only *one* end. See "A Clean Audio Installation Guide" for a more detailed explanation.

## 3.2 Power Supply Considerations

The RPM-1 meter amplifier requires ±15 to ± 18 volt bipolar supplies for the analog circuitry and, if possible, a separate +15 to + 28 volt supply for the lamp and logic circuits. The lamp and logic supply may optionally be provided by the +15 volt supply (assuming enough current is available) via a jumper between bus pins 2 and 4. We assume that a relatively clean source of +12V is available for the meter lamps and logic circuits. If it is not available, provision has been made on the PCB for adding an on-board regulator. If you choose to add the on-board regulator, be sure that adequate input voltage is present to allow the regulator to regulate. The bottom of the AC saw tooth must be at least 1.5 volts higher that the desired +12 V output voltage. See the schematic for the correct circuit values.

## 3.3 Power and Gang-Switch Connections

The nine 3-hole solder busses at the lower left-hand corner of the circuit board are numbered sequentially, with pin 1 nearest the center of the circuit board and pin 9 along the bottom edge. The assignments are as follows:

Pin 1 - analog ground
Pin 2 - +15 to +18 volts
Pin 3 - -15 to -18 volts
Pin 4 - lamp and logic +V, +15 to +28 (+12 with regular removed)
Pin 5 - peak mode (+ pulse in)
Pin 6 - peak hole mode (+pulse in)
Pin 7 - VU mode (+ pulse in)
Pin 8 - peak release (+ pulse in)
Pin 9 - lamp and logic ground

Please note that mode gang-switch inputs must be pulses, *not* static DC voltages. These positive-going pulses may be generated using a normally open momentary push-button switch by connecting it between the +V lamp & logic supply and the appropriate gang switch bus. We strongly recommend an RC network consisting of a 10 kΩ resistor and a 0.1 μF capacitor, be included to create a rather slow voltage transition thus preventing crosstalk on ribbon interconnecting cable and erratic switching conditions. Static DC voltages at the gang switch input terminals will prevent the local mode switches from operating.

Ideally, analog and lamp & logic grounds should be tied together at the power supplies to prevent a sharing of ground currents. In some cases this may not be possible, and a jumper may be installed between pins 1 and 9 or on the board directly above the CD4066.

## 3.4 Local-Switch Connections

The RPM-1 supports local switching as well as gang-switch capability by the use of momentary, normally open, single-pole switches. The switches should be connected between ground (provided by the bottom post of the two pin connectors) and the logic inputs (top post of the two pin connectors) located in the lower left quadrant of the board. The order is as follows:

| | |
|---|---|
| First connector (farthest to the left) | - peak release |
| Second connector (second from left) | - VU mode |
| Third connector (third from left) | - peak hold mode |
| Fourth connector (closest to center) | - peak mode |

## 3.5 Indicator Lamp Circuitry

The RPM-1 will drive either incandescent lamps or LEDs to indicate operating modes.

The indicator drive current available by adding in the optional voltage regulator is thermally limited by the regulator. The drive current available is a function of the current drawn and input voltage to the regulator. If you use the +15V supply to drive the regulator (with, say, a jumper between pins 2 and 4 of the nine pin bus), and assuming a maximum ambient temperature of 50° C (122° F), the device limitation is 1.6 watts. This translates to a maximum current output from the regulator of 533 MA with the +15 volt input. When using an input voltage of +24 V to the regulator, the device will thermally limit at 133 MA. So, as you can see, higher supply voltages result in lower current capabilities. If you need higher current capability than these, it must be provided externally.

The indicator driver transistor assignments are as follows:

| | |
|---|---|
| Transistor 1 (closest to center) - | peak release |
| Transistor 2 (second from center) - | VU mode |
| Transistor 3 (third from center) - | peak hold mode |
| Transistor 4 (farthest to right) - | peak mode |

If external 12-volt incandescent lamps are to be used, such as found within momentary pushbutton switches, wires should be taken from the top and bottom posts of the four pin connectors. If LEDs are to be used as indicators, then an appropriate dropping resistor should be installed between the two upper posts and the wires for the LEDs taken from the two bottom posts. Be careful to observe correct polarity with the LEDs.

If higher voltage (greater than +12V) incandescent lamps are to be used as indicators, a jumper (power option 2) is available to drive the indicator directly with the raw incoming logic and lamp supply voltage (+15 to +28). Remove the vertical jumper wire to the immediate left of the regulator, and install a similar insulated, vertical jumper wire in the holes which are just below and slightly to the right of the original jumper.

The peak LED should be installed with the red wire going to the pin which connects to the pin 2 power bus.

## 3.6 System Reference Selection

Calibration of the LED peak indicator has been factory set at +20 dBu, The meter circuitry is set at +4 dBu in the VU mode and + 12 dBu in the peak mode unless otherwise requested. Basic system reference setup is accomplished with a four position DIP switch located near the top right-hand corner of the board. Switches 3 and 4 set the peak reference, while switches 1 and 2 set the VU reference.

PEAK MODE REFERENCE SELECTION
0 Indication = +8 dBu - Switches 3 and 4 on
+12 dBu - Switches 3 ON, switch 4 OFF
+16 dBu - Switches 3 and 4 OFF

VU MODE REFERENCE SELECTION
0 VU = 0 dBu - Switches 1 and 2 ON
+4 dBu - Switch 1 OFF, switch 2 ON
+8 dBu - Switches 1 and 2 OFF

Switching between system references without much loss in accuracy (± 1/4 dB) is possible. However, for highest precision the system reference levels should be chosen and then fine calibration performed.

### 3.7 Fine Adjustment of Calibration

The amplifier has been adjusted at the factory to match a Sifam VU meter. The use of other meters may require slight adjustment to match the particular rectifier characteristics of the meter.

If only one or two meters are being calibrated make the precision adjustment of level at the output of a function generator for each calibration point, using a precision DVM such as the Fluke 8050A. If, however, many meters are to be calibrated, then a precision attenuator setup is necessary for rapid changing of the precision levels needed for meter calibration. This calibration is best accomplished using the following pieces of test equipment or their equivalent.

1) A function generator,
2) A precision 600 Ω step attenuator set, and
3) A precision digital AC voltmeter. Our preference is the Fluke 8050A.

In your test setup make sure the output impedance of the function generator has been increased (most function generators have an output impedance of 50 Ω) through the use of 550 Ω of build-out resistance to give it a precise 600 Ω output impedance. Likewise, a precision 600 Ω termination must be used at the output of the attenuator.

Adjust the attenuator set for 0 dB of attenuation and then set the output level, using the digital voltmeter in parallel with the RPM-1 card (and at its lowest scale without over-ranging) to the desired level for peak overload calibration, typically +20 dBu. The Fluke is capable of direct dBu readings and should be used in that mode to avoid constant translation from dBu to volts.

| dB/0.775 | 1 kHz AC Voltage |
|---|---|
| +26 | 15.455 volts |
| +24 | 12.277 volts |
| +22 | 9.752 volts |
| +20 | 7.746 volts |
| +18 | 6.153 volts |
| +16 | 4.887 volts |
| +12 | 3.084 volts |
| + 8 | 1.946 volts |
| + 4 | 1.228 volts |
| + 0 | 0.775 volts |

The trim potentiometer nearest the left edge of the board, VR1, sets the level at which the peak LED will illuminate. Adjust the potentiometer until the LED just begins to blink. This may be user-adjusted between approximately +16 and +26 dBu. This adjustment is independent of other calibration settings. Now add the attenuation necessary to bring the level down to the peak calibration point of +8, +12 or +16 dBu depending upon system reference. For instance of the system reference level of +4 dBu is chosen, then the peak section should be calibrated with an input signal whose level is +12 dBu. Adjust the meter to indicate “0” while in the peak mode. The trim potentiometer next to the DIP switches sets the fine calibration for the peak mode. This setting is independent of other calibration settings.

Next, add 8 dB of additional attenuation. Switch to the VU mode and adjust its 0 point. The trim potentiometer between the two meter terminals and nearest the center of the board sets the fine calibration for the VU mode. This adjustment is independent of other calibration settings.

You may find that slight physical movement of the meter while performing these adjustment is necessary in order to overcome any mechanical hysteresis that may be present in the movement, particularly in older moving coil types whose bearing lubrication maybe somewhat congealed. Taut-band meters are less of a problem in this respect.

An 8 dB differential should be maintained between the VU calibration (not quite RMS, but greater than average detecting rectifier) and the peak calibration. Both ABC in New York, and the CBC in Canada have affirmed this ratio as being the correct ratio for program material that has been processed at least one time. See reference 1 for more information.
This completes the calibration of the meter.

## 4.0 Modifications

The following modifications may be made to the RPM-1 meter driver card.

### 4.1 Time Constants

Changes may be made in a number of areas to the RPM-1 according to the needs of the user. The first area that may be desirable is a change in the time constants involved in the peak mode. By studying the schematic, it will become obvious that the drive transistor that feeds the change capacitor is not necessary with the 2K Ω resistor in place. It is included for those who wish to lower the attack time constant for faster response over the IEC determined constant. It would be well to not go lower than 50 Ωs thus limiting the demand on the drive transistor and preventing overshoot in the peak detector.

### 4.2 -10 dBV Calibration

As noted earlier, -10 dBV is the same as -7.78 dBu. To bring the 0 dBu setting into range the differential input stage, with a normal loss of 12 dB must be changed to have a loss of only 4 dB. This may be accomplished by replacing the 12.4 kΩ feedback resistors with 31.4 kΩ resistors. The peak overload calibration will now also be ≈8 dB lower, that is for an original +20 dBu calibration the cal will now be ≈ +12 dBu or ≈ +10 dBV. Next set all of the dip switches ON for a 0 calibration of -10 dBV in the VU mode and -2 dBV in the peak mode. Using the procedures described above, calibrate the card using a precision digital multimeter such as the Fluke 8050A. Remember there is a 2.22 dB correction factor between the reading on the dBm related scale of the multimeter and the desired dBV calibration points.

### 4.3 150 Ω Operation

The reference voltage for the 0 dBm 150 Ω system is exactly one half that of the 600 Ω system. Therefore, the correct method for using the RPM-1 in a 150 Ω system is to replace R4 and R5 feedback resistors with 24.9 K Ω resistors and to operate the input stage at -6 dB of gain instead of -12 dB. All calibrations will then be the same as with the 600 Ω system, that is the 0 dBm system reference, as used by CBS, will require all switches to be in the ON position.

### 4.4 Pre-Emphasis Networks

It is a simple matter to turn the RPM-1 into a deviation meter to monitor a FM STL. By replacing the second stage of the input filter with a new set of components, the required pre-emphasis is obtained. The following chart gives the recommended values for various time constants. As an additional possibility, a complete bank of pre-emphasis networks may be mounted on a switch along side of the RPM-1 and the user may then have his choice of time constants. This modification requires the replacement of R4 and R5 with 24.9 K Ω resistors, and the removal of all of the components in the second stage of the input filter. The first stage of the filter is left intact. The diagram for the modified second stage is given below in Figure 2.0.

The operation of the pre-emphasis network is as follows. The four components shown in figure 3 will create the curve shown in figure 2. The first break point of the curve is set by components R1 and C1. The frequencies at which the 3 dB points come into play is defined by:

$$F = \frac{1}{2\pi RC}$$

The upward slope is created by the fact that as frequency increases the $X_C$ of C1 is constantly dropping and the gain of the circuit increases directly with C1 and R1 setting the gain. $f_2$ is set by C1 and R2. At $f_2$ the $X_C$ of C1 is equal to the resistance of R2 which is the gain-limiting resistor and the curve begins to flatten. The maximum gain of the circuit is set by R1 and R2, as defined by,

$$A_{max} \text{ (in dB)} = 20 \text{ Log } \frac{R1+R2}{R2}$$

The third time constant f3 is set by C2 and R1 and is intended to limit the high frequency noise of the amplifier stage.

| Time C | f1 | R1 | C1 | R2 | C2 | MAX A | f2 | f3 |
|---|---|---|---|---|---|---|---|---|
| 25 µ sec | 6.37 kHz | 11.5 kΩ | 0.0022 µF | 1.82 kΩ | 220 pF | 17.5 dB | 39.7 kHz | 62.9 kHz |
| 50 µ sec | 3.18 kHz | 22.6 kΩ | 0.0022 µF | 1.82 kΩ | 100 pF | 22.6 dB | 39.7 kHz | 70.4 kHz |
| 70 µ sec | 2.27 kHz | 31.6 kΩ | 0.0022 µF | 1.82 kΩ | 68 pF | 25.3 dB | 39.7 kHz | 74.1 kHz |
| 75 µ sec | 2.12 kHz | 34.0 kΩ | 0.0022 µF | 1.82 kΩ | 68 pF | 25.9 dB | 39.7 kHz | 68.8 kHz |
| 90 µ sec | 1.77 kHz | 41.2 kΩ | 0.0022 µF | 1.82 kΩ | 56 pF | 27.5 dB | 39.7 kHz | 69.0 kHz |
| 120 µ sec | 1.33 kHz | 54.9 kΩ | 0.0022 µF | 1.82 kΩ | 47 pF | 29.9 dB | 39.7 kHz | 61.7 kHz |

**Figure 1.0 Time Constant Component Values**

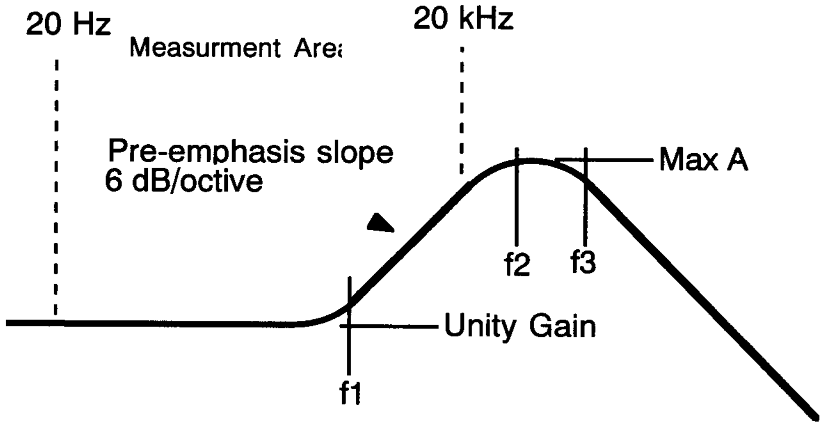

**Figure 2.0 Pre-emphasis Curve**

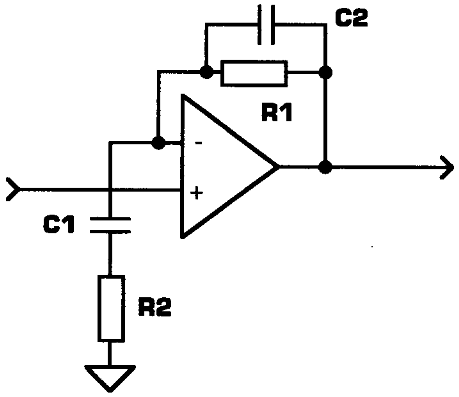

**Figure 3.0 2nd Stage Circuit Modification**

## 5.0 Further Reading

A paper by the late Hans Schmid, entitled "The Peak Program Meter and the VU Meter in Broadcasting"[1] is an excellent source of information concerning the advantages of peak program meters. This paper was presented at the 67th convention of the Audio Engineering Society in New York, 1980, preprint #1691 (I-8). Preprints may be obtained by contacting,

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This completes the RPM-1 manual.

Edited October 5, 1998

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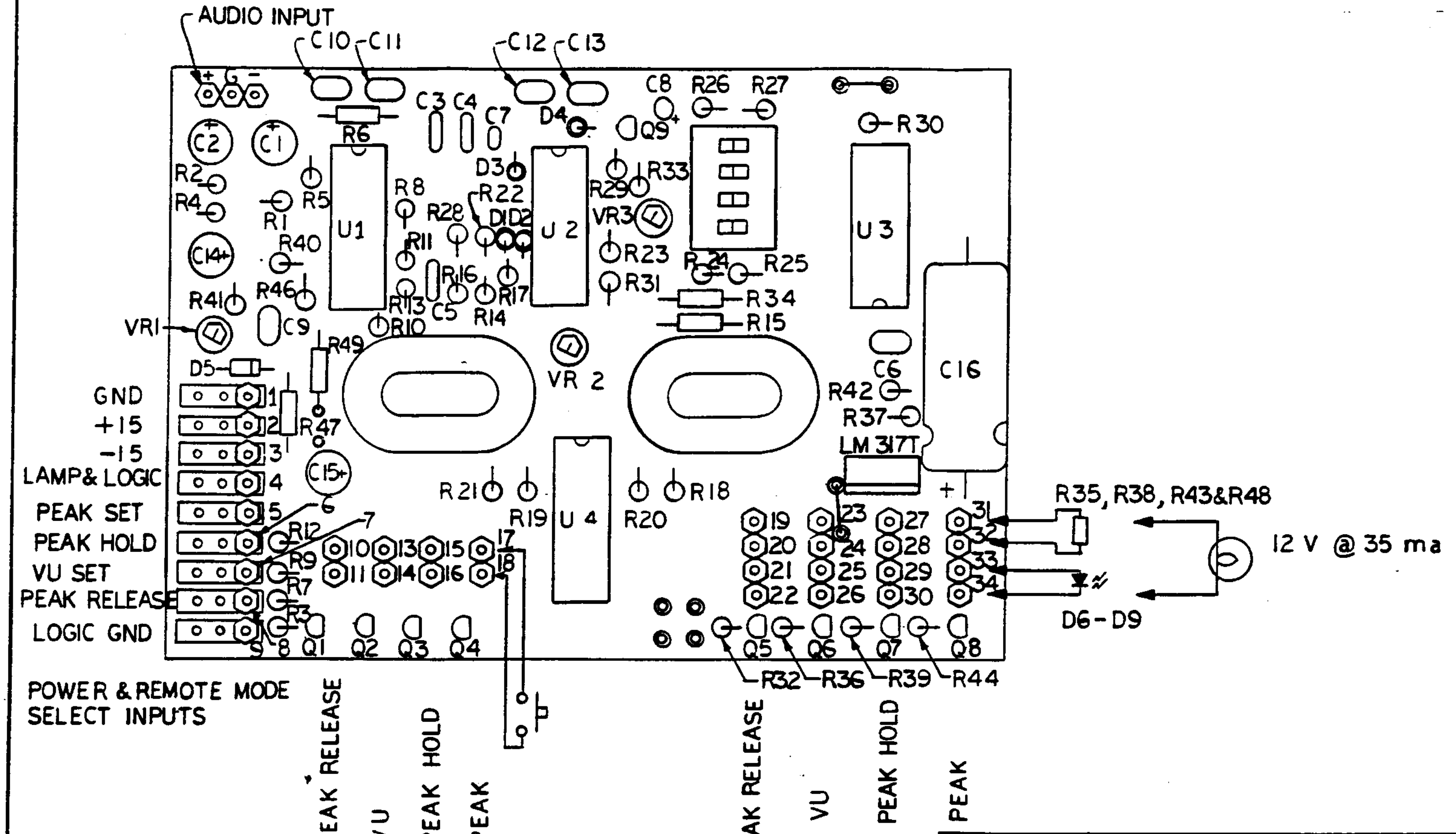

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