

Library 12

Jensen & John Hardy



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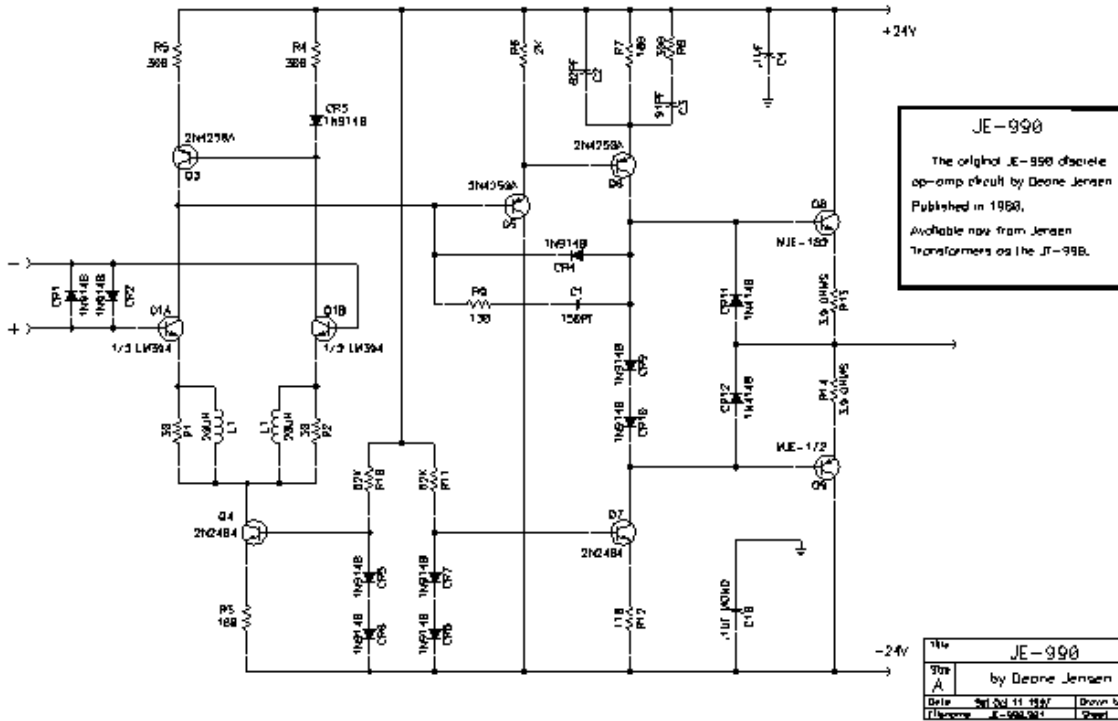
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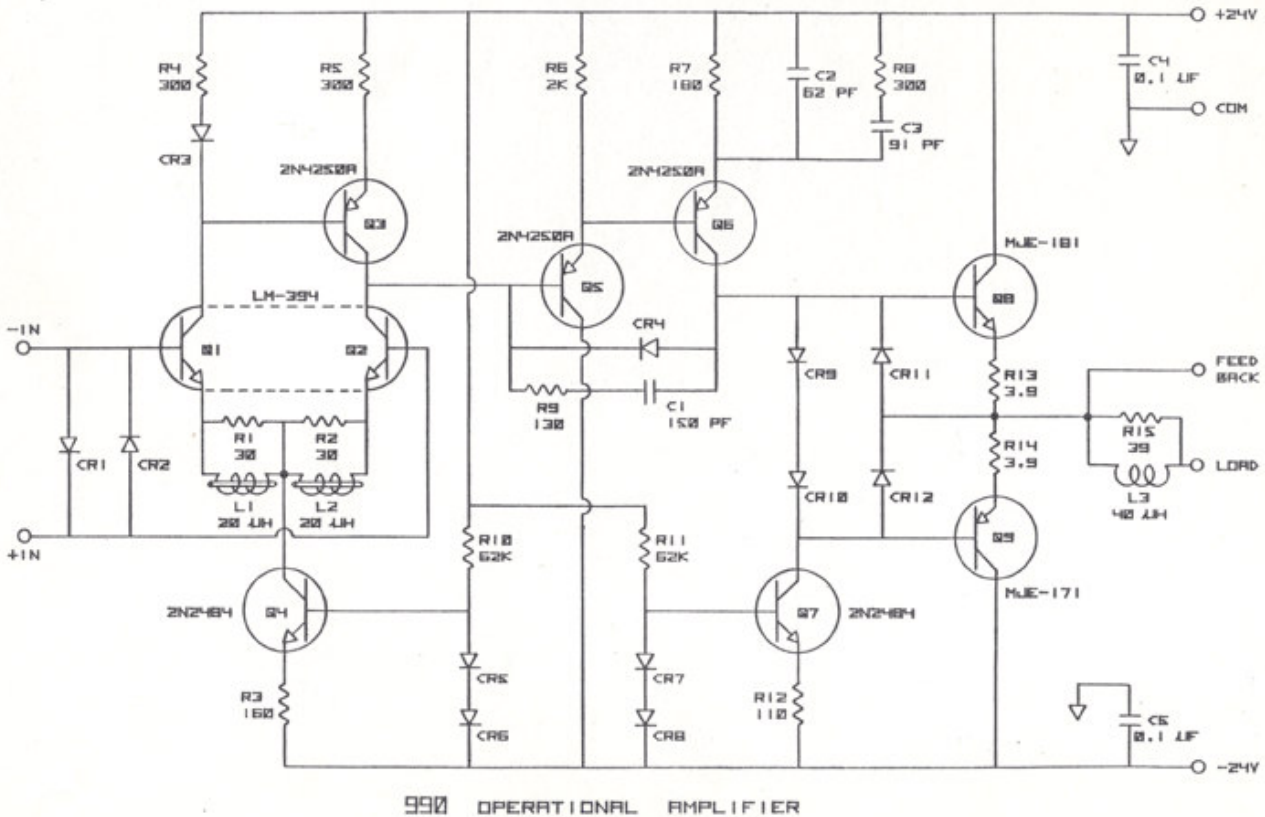
990 operation amplifiers of 1980's.



JE-990



JE-990-1



JE-990-2

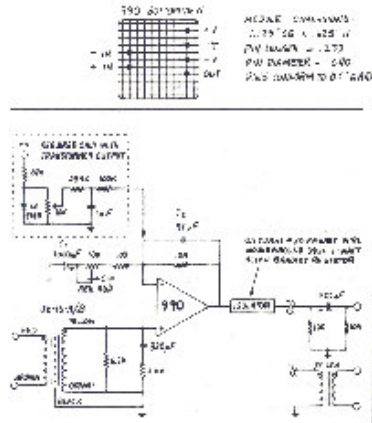


FIGURE 1: MICROPHONE PRE-AMPLIFIER

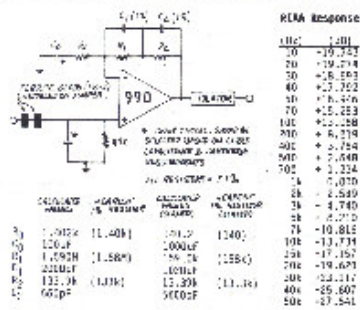


FIGURE 2: PHASE PRE-AMPLIFIER

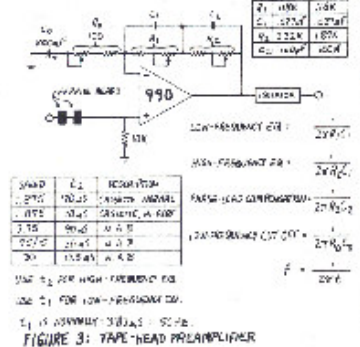


FIGURE 3: TAPE HEAD PRE-AMPLIFIER

THE JOHN HARDY CO.
 1728 Diamond St. Evanston, IL 60122 USA
 P.O. Box 84231, Evanston, IL 60224 USA
 Phone 815-884-9080

APPLICATION NOTES

FOLLOWING ARE SEVERAL CIRCUITS FOR USE WITH THE 990 DISCRETE OPERATIONAL AMPLIFIER. WITH THE PROPER ATTENTION TO DETAIL, YOU SHOULD ACHIEVE EXCELLENT RESULTS.

MICROPHONE PRE-AMPLIFIER

Figure 1 shows a traditional transformer-coupled microphone pre-amplifier. The complete circuit is adjustable from 11.6 to 42.3 db of gain, including the transformer step-up of 5.3 db, with a bandwidth of 172 kHz (3 dB). The Jensen JE 16-2-E 1000-turn input transformer was chosen specifically for the 990. It is used to keep the DC offset of the 990 constant by decreasing the gain-adjust pot wire adjustment. Because the inverting input would see a changing DC resistance to ground with the non-inverting input and a fixed resistance, the 990 DC voltages develop at various inputs as the input bias current resistances. If both inputs see identical DC resistances, they will develop the same voltages. When identical voltages at the inputs share with a no DC offset at the output, since the output of an op-amp is determined as the difference between the two inputs. With different DC resistances at the inputs, the offset will appear at the output. If a wire adjustment pot were used, the DC resistance at the inverting input would change the DC offset to change, but this means using a new wire to change gain at 100 ohm increments instead of using gain at 10 regardless of pot setting, with 0.1% difference of only a couple of volts at the input would give you a couple hundred millivolts at the output of the op-amp. It also shows a typical offset compensation. The offset voltage at each input is found by multiplying the input bias current (9.2 uA) by the DC resistance seen at that input. For the non-inverting input, the DC resistance is the transformer secondary resistance parallel to the 250K load resistor. For the inverting input, the DC resistance is the only DC path, since the closed-loop DC gain of the amplifier is unity, the DC offset at the output is equal to the difference of the offset voltages at the two inputs. The compensating current required into the inverting input is the offset voltage divided by the feedback resistance (100K). This DC offset compensation will significantly reduce the DC offset at the output for these applications without an output coupling capacitor.

It provides the offset compensation with a high-frequency cutoff of 175 kHz.

The use of a capacitor in series with the network as a means of controlling DC offset is traditional. So too is the use of an output capacitor. For a differential and superior approach that eliminates these capacitors, please see the appropriate circuit in MICROPHONE PRE-AMPLIFIER WITH ZERO CONTROL OF DC OFFSET, found later in these notes.

PHASE PRE-AMPLIFIER

Figure 2 shows a phase pre-amplifier with related component values and approximate Bode response figures. The circuit will result in an extremely accurate Bode response, typically better than 0.1 dB, provided the values and tolerances are maintained. The values are taken from a paper by Lushitzki (1) which thoroughly covers Bode equalization methods and their error design. For specific design information, formulas, etc. refer to that paper.

Figure 3 shows the Bode calculated as above and component values as listed in the paper, with the closed loop transfer values shown in parenthesis. Column 2 shows these values scaled by a factor of 10, to take advantage of the frequency noise figure of the 990 at lower source impedances.

By decreasing the source impedance DC offset will be better. It could be eliminated if offset compensation were performed. See MICROPHONE PRE-AMPLIFIER for more information.

The 990's DC offset at the input are optional to reduce BJT. The circuit will be approximately 41.7 db at 1 kHz. See tolerances or component values should be carefully evaluated based on the datasheet paper.

REFERENCES

- 1. Lushitzki, S., "Bode Equalization Networks", Journal, Avia Engineering Society, Vol. 23, No. 6, 6179, Pt. 458-481.

TAPE HEAD PRE-AMPLIFIER

Figure 3 shows a tape head pre-amplifier. Component values for 3.75 and 7.5 dB of gain equal values with a gain of 30 db are listed. Other gains and equalizations are partly achieved using the formula provided. Tape head specifications and characteristics vary widely, so the values listed will probably require tweaking, and the final results should be carefully examined for any irregularities.

Tape heads with extremely low input levels will require additional gain, and a low-noise op-amp should be considered for that purpose. The 990 op-amp should have flat response, and even to-amp should be set for equal gain at high frequencies (20 kHz).

The circuit is very sensitive to the BJT noise present, except that this one is minimal, and the 990's output is at 100 ohm impedance, which is desirable, and the 990's output is at 100 ohm impedance. See MICROPHONE PRE-AMPLIFIER for comments on C_1 and ferrite beads.

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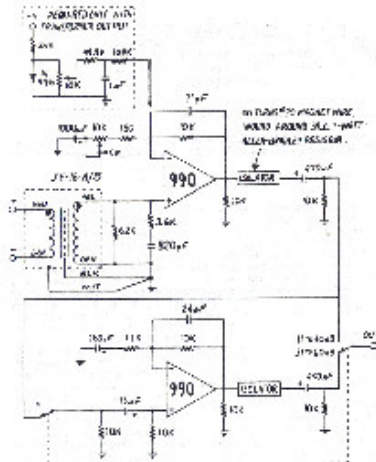


FIGURE 4: TWO-STAGE MICROPHONE PREAMPLIFIER (COURTESY OF JENCO ELECTRONICS)

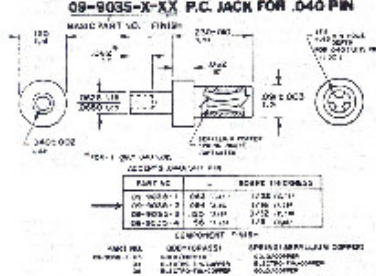


FIGURE 5: SOCKET FOR .040D PIN

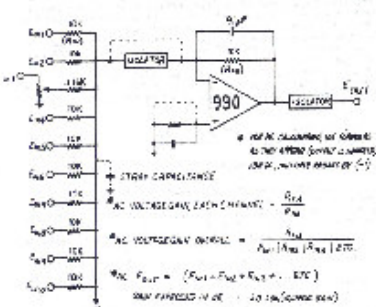


FIGURE 6: SUMMING AMPLIFIER (INVERTING)

THE JOHN HARDY CO.
 172E Burnside St. Easton, IL 62022 USA
 P.O. Box A4551 Easton, IL 62024 USA
 Phone: 618-384-3888

TWO STAGE MICROPHONE PREAMPLIFIER

Figure 4 shows a two-stage transformer-coupled microphone preamplifier. It is designed for situations where extremely high gain is required. The gain is essentially that of the single-stage preamp of Figure 1, except the maximum gain is about 5 dB lower. A practical 2nd stage with 20 dB of gain makes a class of single-stage preamp of to 40 dB of gain (including transformer-coupled or two-stage operation with up to 60 dB of total gain). The 2nd stage could be changed from fixed to adjustable gain. Ideally, each stage would have the same amount of gain in the high-gain amplifiers, and a variable 2nd stage would allow gain reduction at low overall gain.

Offset voltage compensation can be performed on the 1st stage, as described in the single-stage manual. Note that the 2nd stage will have a low gain because the inverting and non-inverting inputs are about 10:1 ratio resistor values.

SOCKETS

Two types of sockets are available from several manufacturers. A common socket is shown in Figure 5, reprinted from the Harco catalog. The same part is available from Carlin as well. This socket is available from stock from the Hardy Co. (see the price list).

This particular socket may be soldered in place, or swapped (special tool required).

CONCRETE ELECTRONICS CORP. (616) 274-8570
 30 Great Jones St.,
 New York, NY 10012 Part #20-0238-2-02

CONELCO (617) 491-8400
 485 Concord Ave.,
 Cambridge, MA 02138 Part #450-2755-02-03

A good selection of sockets is also available from:

ROBINSON ELECTRIC INC. (615) 345-0211
 901 E. 8th St.,
 New Albany, IN 47150

SUMMING AMPLIFIER

Figure 6 shows a summing amp with several optional features. Some applications require signals to be combined at unity gain, others require different gains. For example, the signal of channel 5 is attenuated by a potentiometer (typically 10:1 of attenuation) just before it enters the summing circuit. To restore the 10:1 loss through the pot, a lower value is used for R_{51} in this case (3.3k is recommended). With more channels being summed simultaneously, the overall common-mode signal at the output of the summing amp could become noticeable, resulting in frequency feedback. The final value for R_{51} would therefore be chosen based on the number of channels, signal levels, and load impedance, etc.

The non-inverting input may be grounded directly, or through a resistor. The value of this resistor should equal the DC source resistance seen by the inverting input, which is the parallel resistance of all the input resistors and the feedback resistor R_{f1} and R_{f2} , with both inputs of the 990 summed external DC source resistances, the audio offset voltage will be lowest. This resistor can result in increased noise when connected to a directly terminated input. This problem can be overcome by adding a capacitor in parallel with this termination resistor. The capacitor has infinite impedance at 0Hz, so the terminating resistor is the only factor as far as DC noise are concerned. The impedance of the capacitor becomes much lower than that of the terminating resistor above 100, so the noise performance of the 990 is not significantly compromised. The value of the capacitor will depend on the noise performance of the type of op amp being used, number of channels being summed, noise limitations of the channel being summed, etc. A value of 10µF would be a place to start.

Note that the actual termination point of feedback for the non-inverting input is critical. If longer conductors with many inputs, there can be much noise appearing at the ground bus, since even a heavy ground bus will have a small but measurable resistance, with voltages appearing across the resistance. These voltages can be in the form of power-supply noise, return-current (bus voltages) from other modules, etc. Although each type of the summing amp may do at unity gain, the overall gain of the summing amp is determined by using the parallel resistance of all the input resistors for the value of R_{51} in the gain formula. For example, 24 inputs with 10k of the results in a final parallel resistance of 417 ohms, for a voltage gain of 24 (27.6 dB). That is, the more the ground bus noise would be amplified if the non-inverting input were terminated for more the signal source impedance. Grounding is critical!

Larger summing buses cause increasing amounts of stray capacitance to appear at the inverting input. This capacitance causes phase shift in the feedback signal, and if sufficient quantities, can cause oscillation. Additional capacitance can be used in the feedback loop to compensate. Use an inductor (normally part of the output of the 990) can be inserted between the summing bus and the inverting input, with the inductor in place by the inverting input as possible. The inductor has an impedance of 6.28 ohms at 100, which is only 5 times at 20 kHz, so the audio bandwidth passes through relatively unaffected. Above 100 kHz, the impedance is 39 ohms, reducing the effects of the stray capacitance.

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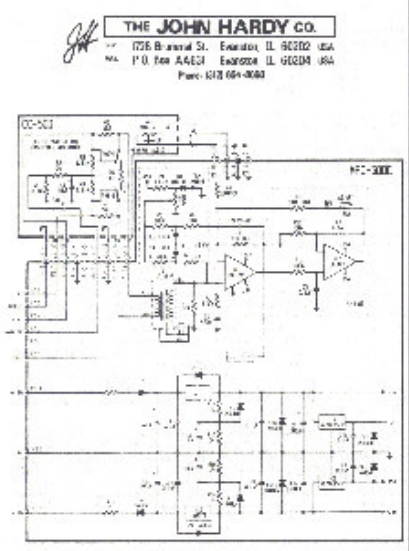


FIGURE 7c MFC-500C Mic-Preamp Card & CC-500 Control Card

MICROPHONE PREAMPLIFIER WITH SERVO CONTROL OF DC OFFSET

Figure 7 shows a single stage microphone preamplifier with a special servo circuit, input bias current compensation circuit, and reduced power dissipation. The circuit is similar to the design shown in Figure 1, because the servo and input bias current compensation circuits now control the DC performance of the circuit, making it possible to eliminate the gain-set resistor and output capacitor. This results in a substantial improvement in audio quality since even the best film capacitors are a compromise.

As discussed in the earlier application note "SINGLE STAGE MICROPHONE PREAMPLIFIER", gain-set adjustments without the use of a gain-set resistor (R₁ in Figure 1) would cause changes in the DC offset of any op-amp. These offsets result from drift due to time and temperature. A capacitor in series with the output is often used to keep these various offsets from reaching the outside world.

With the servo approach, the LM103 operates to reduce the output of the 990 for the presence of any DC offset and provides a corrective voltage to the inverting input of the 990, nulling the DC offset of the 990 in with the DC offset of the LM103 itself.

There are two input bias (polysilicon) in the servo circuit, but the only signal that is affected by these capacitors is the ultra-low frequency and DC components. These capacitors are working with their respective resistors as a low-frequency impedance network. Essentially, the only signal that passes through the servo circuit is the DC offset of the 990. The audio bandwidth is completely unaffected. The servo keeps the DC offset of the preamp circuit well below 1 mV under normal conditions.

The LM103 was chosen as the servo amp because it has exceptional DC characteristics, with a typical offset voltage of 0.2 mV and a drift of .02 mV per degree centigrade of temperature change. Since the servo preamp only sees extremely low frequency signals, it does not need a high slew rate.

An input bias current compensation circuit is also shown. It performs two important functions. First, it nulls the small DC voltages that appear at the inputs of the 990 due to the normal flow of input bias current. This eliminates the noise that would be caused during gain set adjustment, caused by DC voltage across the pot. Second,

since the input bias current is compensated for and the DC voltages at the inputs are nullified, the DC offset of the 990 will no longer change as the gain pot is moved. Without this circuit, the offset of the 990 could drift as much as 100 mV during coarse changes of gain (low to 100, or vice versa), the most serious depending on the specific input bias current and DC offset of the individual 990. Smaller gain changes would cause smaller offset drifts. It is important to note that the servo circuit would still reduce the larger drifts to less than 1 mV in just a few seconds, but the bias compensation circuitry eliminates these drifts and compensates. The servo circuit's only task then is to deal with the inherent DC offset of the 990. The complete adjustment procedure for the input bias compensation circuit is shown below. The pot of LM103 of course provides a reference voltage of 0.2 volts. The DC trimmer adjusts this voltage and applies it to the inputs of the 990 as a current through the 100K resistors. The 100K polysilicon capacitors act as low-pass filters to remove noise from the compensation circuit.

Figure 7 shows the complete circuitry of the MFC-500C mic preamp card and the CC-500 control card, receipts for the MFC-500C series controls. Data cards are available from The Harry Co. The MFC-500C audio boards of values for 5000 of the parts. The first values shown are those used in the stock MFC-500C card, and are chosen for compatibility with the 10K gain-adjust pot in the MFC control. The values in parentheses are preferred because they will provide a 1 to 2 dB improvement in SNR ratio. A 10 ohm resistor of the MFC-500C is adjustable. The CC-500 control card is available in MFC-compatible and low noise versions, making conversion of the MFC control possible. The former resistor values of the stock MFC-500C (and the pot) of Figure 7 are a necessary change to meet the value, size and cost of the conventional gain-set resistor from becoming too great. Elimination of this capacitor corrects these restrictions, making the user value resistor available.

The only real power supply is shown on the MFC-500C card to excellent for any audio application. There are actually two sets of regulators. The first set (LM317 and LM337) serves the 990 and supplies of the 990 controls down to the 990 volts required by the 990-500 circuit. The second set (LM315 and LM316) provides a lower supply voltage for the LM103, which is rated on a maximum of 20V volts. The 2nd set of regulators could be eliminated by using the 990-100 or 990-100 and setting the main regulators at the appropriate lower voltage. However, headroom would be reduced by as much as 4 dB due to the reduced supply voltage (21V with loading).

The power supply as shown requires a minimum of +12 volts per grosser capacitor due to the individual differential cost of the 517333 regulators and the voltage drop of the 25 ohm resistors (R1 and R2). These resistors provide more effective filtering, but can allow if either supply is shared in ground. Alternatively, they can be eliminated.

The LM317/337 regulators are similar to the conventional 7800-7900 or 240/320 three-terminal regulators, but offer improved performance in a number of areas. There are several diodes used in the circuit. The input diodes protect the regulators from reverse polarities. The balance of the diodes protect the regulators and op-amps from various possible destructive waves. These diodes are absolutely required. For complete details on the diodes, consult part numbers, etc., consult the manufacturers data sheets.

The LM317 and LM337 regulators are available from National Semiconductor and Texas Instruments. The 7815 and 7915 are common items available from several different manufacturers. The LM103 amp is available from National Semiconductor and Motorola.

The servo circuit can be applied to virtually any audio circuit. There are many variations. For complete details, a good reference is an article by Brian Clark in The Audio Amateur, issue 3/1982. Contact The Audio Amateur, P.O. Box 576, Peterborough NH 03462.

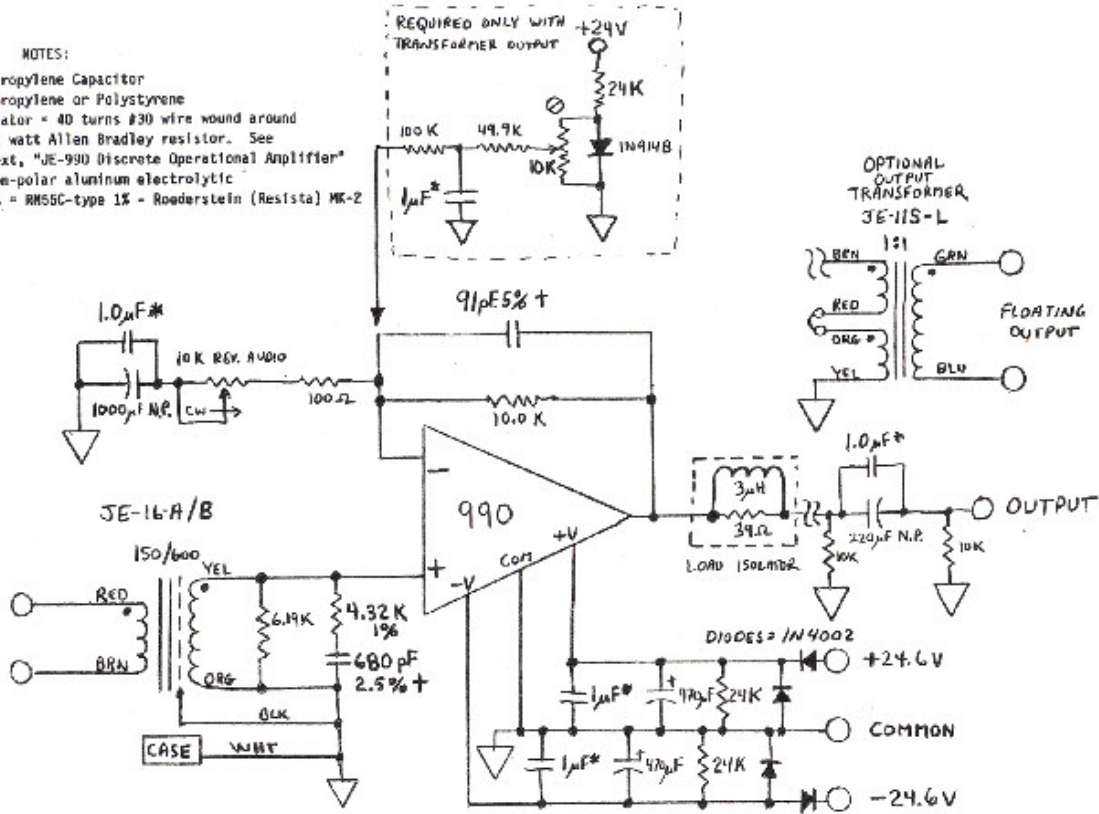
ADJUSTMENT PROCEDURE: A DC voltmeter with 0.1 mV resolution of accuracy is required. Note: The 990 pot is a precision 25-turn device.

1. Allow the MFC-500C to warm up (15 minutes minimum).
2. Move the slide switch (SW1) on the MFC-500C to the "GAIN" (ADJUST) position.
3. Connect the DC voltmeter to the output of 990, at the output connector.
4. Measure and record the DC offset of the 990 with the pot adjusted to MAXIMUM, that MINIMUM.
5. If the bias compensation trimmer is correctly adjusted, the two measurements you just made will be equal within 1 mV of each other. The measurements could be as much as 100 mV or more, as long as they are equal. Adjust the trimmer and repeat steps 4 and 5 until the measurements are equal. When they are, the input bias current of the 990 has been completely nullified.
6. Move the slide switch to the "RFL" position. The LM103 will quickly null the remaining DC offset to less than 1 mV, and the offset will remain there even during coarse adjustments of the gain pot. If the compensation trimmer were out of adjustment, the DC offset of the 990 could temporarily go as high as 100 mV during coarse gain adjustments (low to 100, or vice versa). Even then, the LM103 would null that offset to less than 1 mV in a couple of seconds.

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NOTES:

1. * = Polypropylene Capacitor
2. † = Polypropylene or Polystyrene
3. Load Isolator = 40 turns #30 wire wound around 39 Ohm, 1 watt Allen Bradley resistor. See Jensen Text, "JE-990 Discrete Operational Amplifier"
4. N.P. = Non-polar aluminum electrolytic
5. Resistors = RM55C-type 1% - Roederstein (Resista) MK-2



SIMPLE MICROPHONE PREAMP WITH OFFSET COMPENSATION & 12 TO 45 dB ADJUSTABLE GAIN
REV. 3-20-84

JE-990-6

JENSEN TWIN SERVO MICROPHONE PREAMPLIFIERNOTES

1. *Capacitors = $\pm 10\%$ polypropylene or polycarbonate
2. †Capacitors = $\pm 2.5\%$ Polystyrene or Polypropylene (Mallory SXM Series or equal)
3. Resistors are RN55C-type 1% metal film; Roederstein (resista) MK-2 preferred
4. All diodes = 1N4002 unless marked otherwise
5. Servo amplifier = LM11C
6. +18 Volt Regulator = LM317L
7. -18 Volt Regulator = LM337L
8. Trimpots = Multiturn Cermet, Bourmes 3006P or 3299 series or equal
9. Load Isolator = 40 turns of #30 Magnet wire around a 39 ohm, 1-watt Allen Bradley resistor.
10. Gain Adjust = Reverse Audio taper, dual, 1K conductive plastic potentiometer
11. **100 Ohm 2 Watt Metal Film Roederstein (Resista) MK-8 Preferred

CAUTION

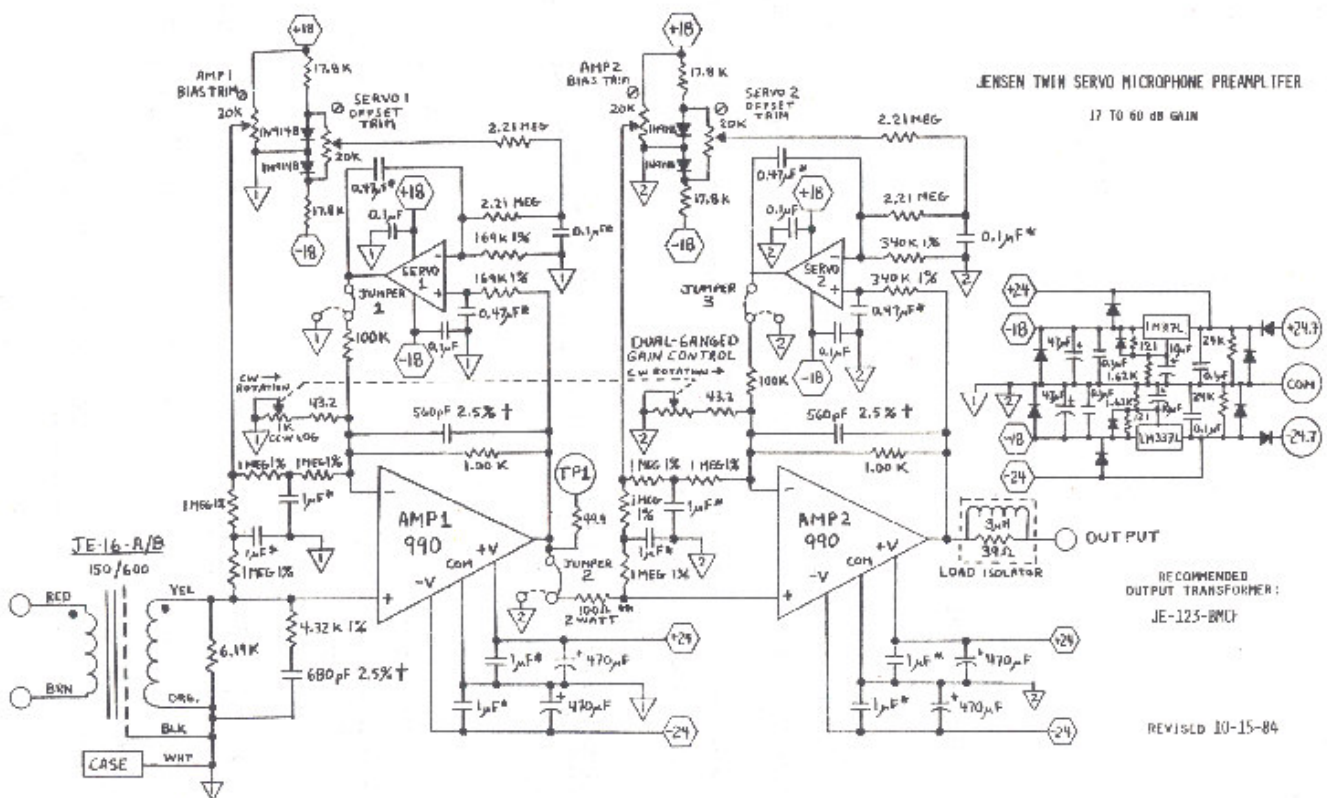
Protect speakers from damage due to preamp's turn-on and turn-off D.C. transients. Use A.C. coupling or A.C. operated relay to prevent catastrophic "thumps".

Adjustment Procedure

1. With all 3 jumpers to dotted line position, bring 990's to operating temperature before adjusting bias.
2. Monitor TP1 and adjust 'Amp 1 Bias Trim' for minimum offset change between minimum and maximum preamp gain.
3. Connect Jumper 1 to solid line position, and adjust 'Servo 1 Offset Trim' for 0 μ V offset.
4. Monitor Output and adjust 'Amp 2 Bias Trim' for minimum offset change between minimum and maximum preamp gain.
5. Connect Jumper 2 to solid line position. Slightly readjust 'Amp 2 Bias Trim' if necessary for minimum offset change between minimum and maximum preamp gain.
6. Connect Jumper 3 to solid line position and adjust 'Servo 2 Offset Trim' for 0 μ V offset at preamp output.

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