Library 12

Jensen & John Hardy

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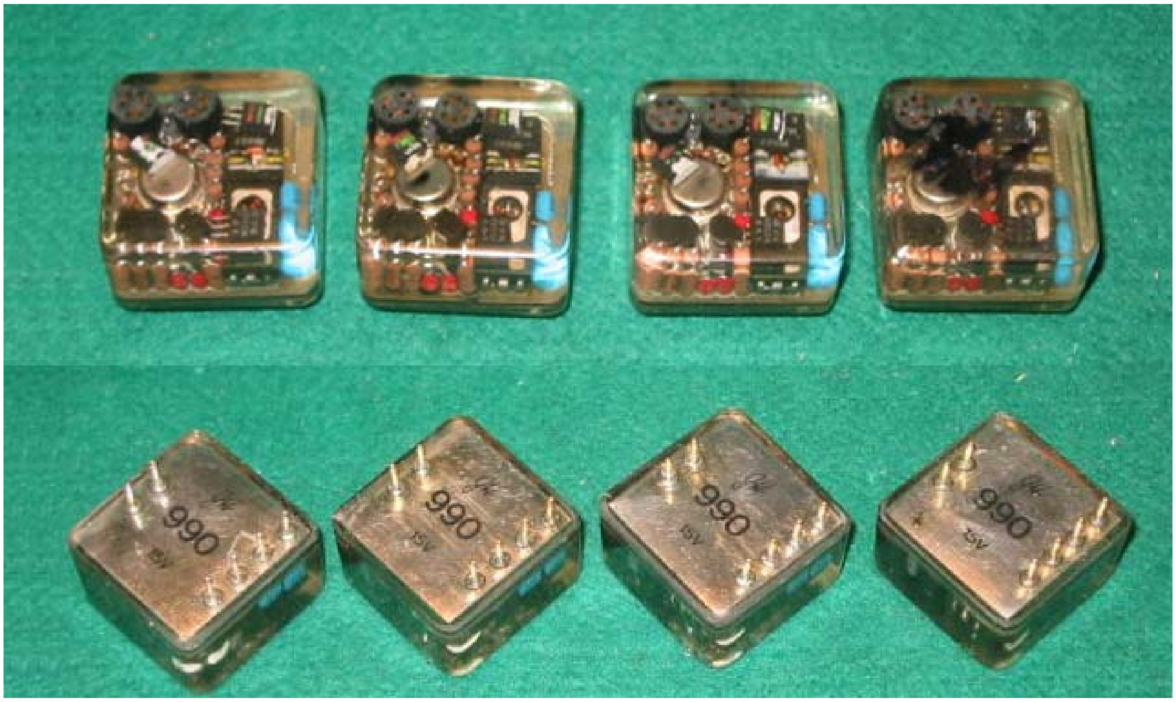
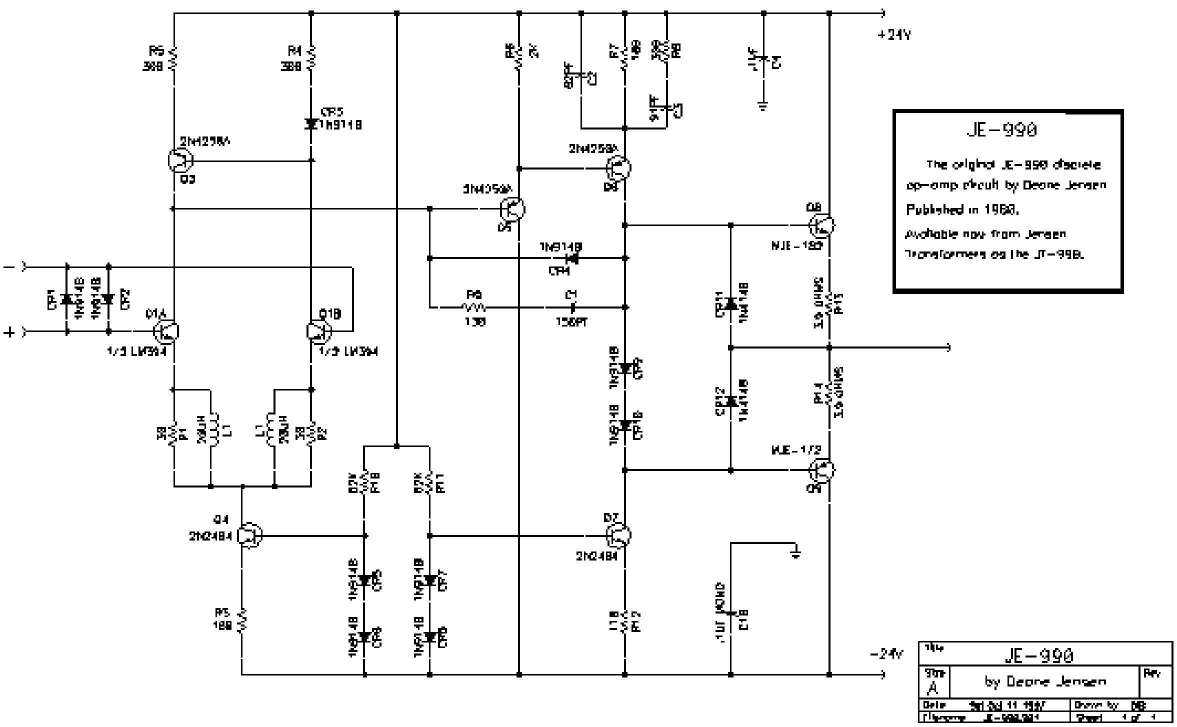
990 operation amplifiers of 1980's.



JE-990

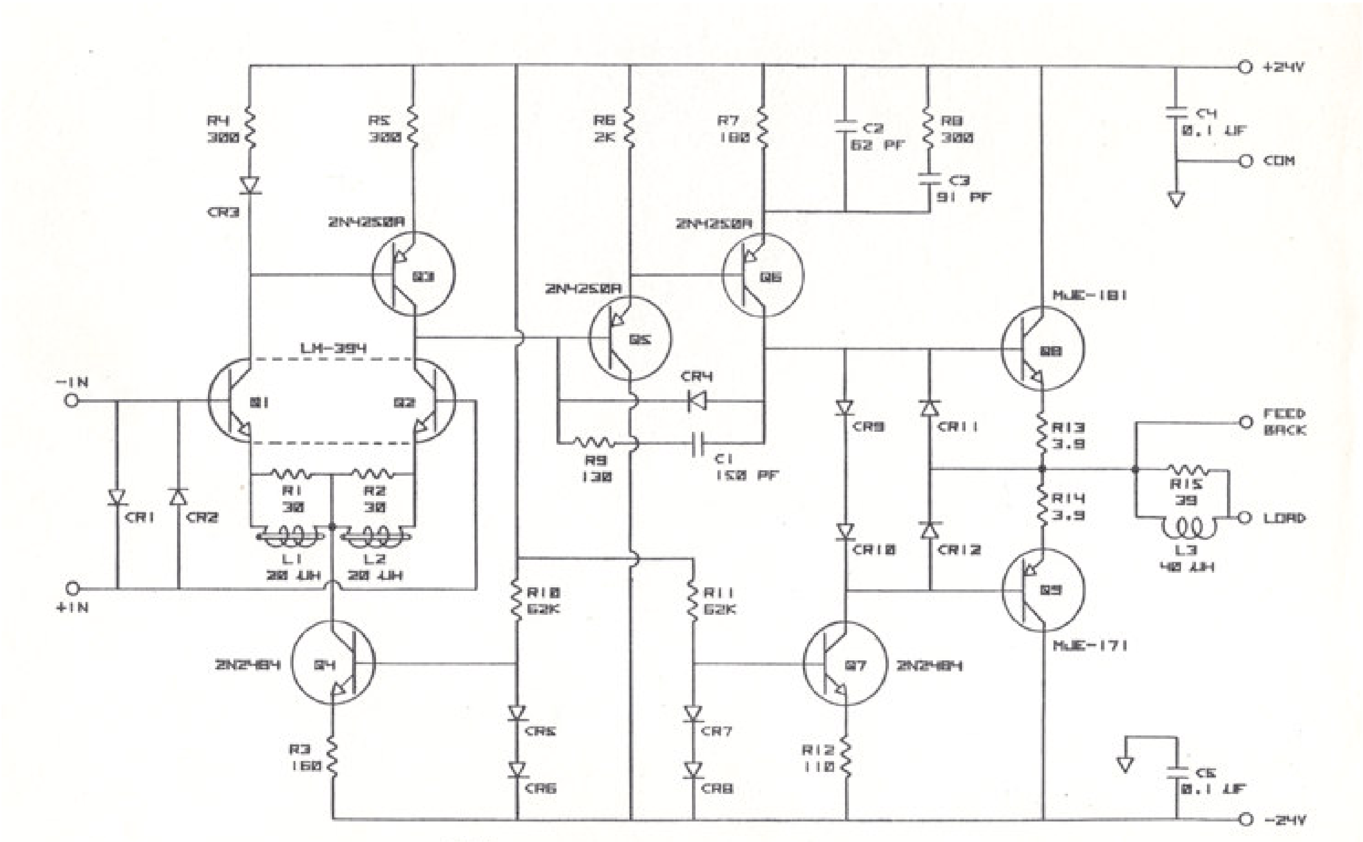


JE-990

The original JE-990 discrete op-amp circuit by Deane Jensen Published in 1980.

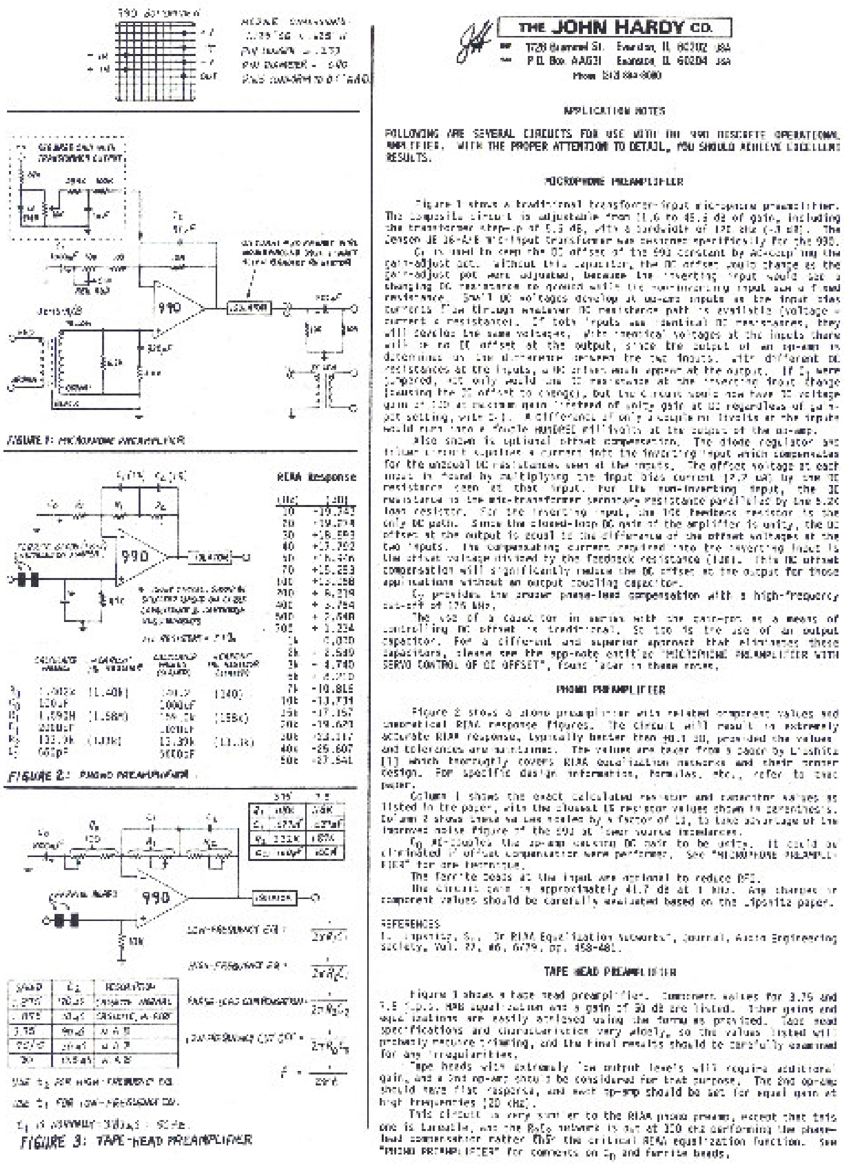
Available now from Jensen Transformers as the JT-990.

JE-990-1



990 OPERATIONAL AMPLIFIER

JE-990-2



THE JOHN HARDY CO.

P.O. Box AA631 Evanston, IL 60204 USA

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 PREAMPLIFIER

FIGURE 1: MICROPHONE PREAMPLIFIER

PHONO PREAMPLIFIER

FIGURE 2: PHONO PREAMPLIFIER

REFERENCES

TAPE HEAD PREAMPLIFIER

FIGURE 3: TAPE-HEAD PREAMPLIFIER

JE-990-3

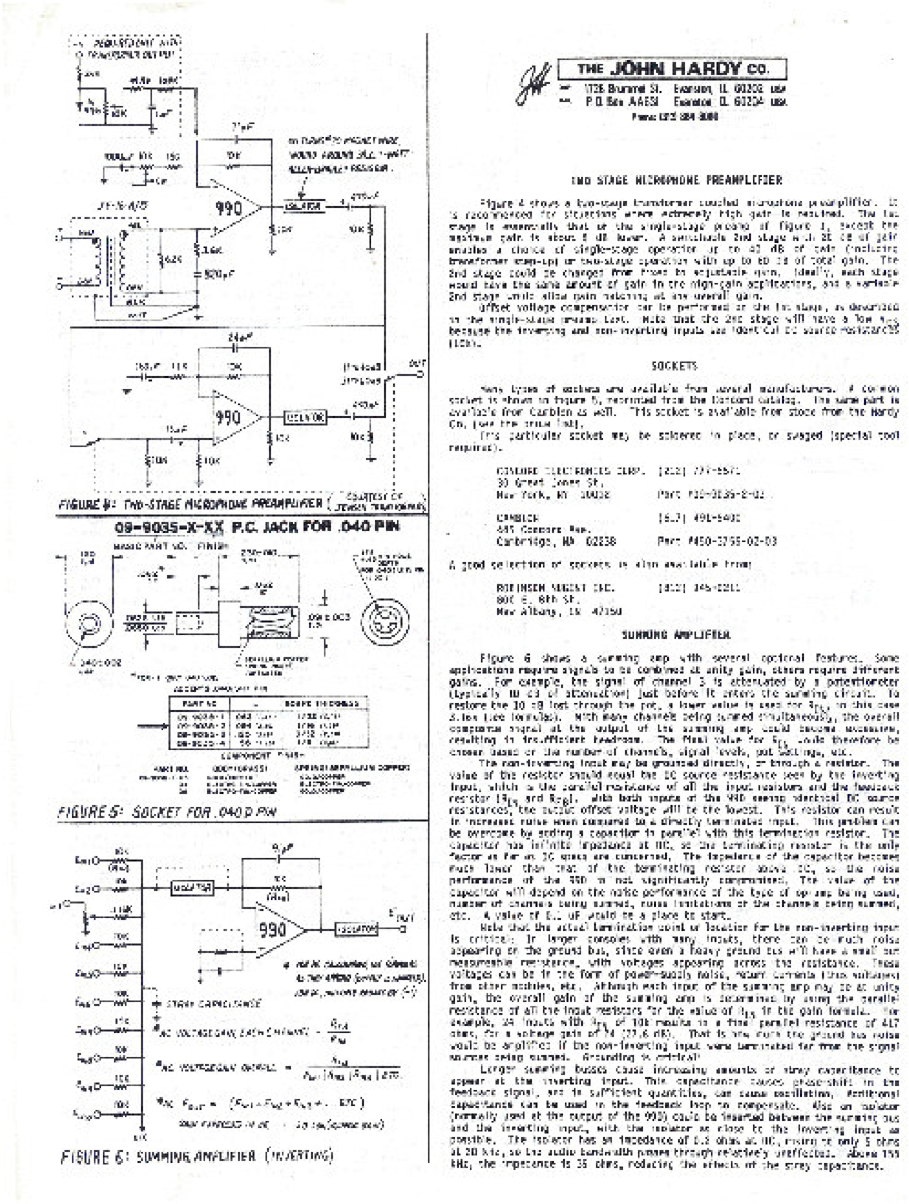


FIGURE 4: TWO-STAGE MICROPHONE PREAMPLIFIER (COURTESY OF JENSEN TRANSFORMERS)

09-9035-X-XX P.C. JACK FOR .040 PIN

FIGURE 5: SOCKET FOR .040 D PIN

FIGURE 6: SUMMING AMPLIFIER (INVERTING)

THE JOHN HARDY CO.
1728 Brummel St. Evanston, IL 60202 USA
P.O. Box AA631 Evanston, IL 60204 USA
Phone: (312) 864-8060

TWO STAGE MICROPHONE PREAMPLIFIER

Figure 4 shows a two-stage transformer coupled microphone preamplifier. It is recommended for situations where extremely high gain is required. The 1st stage is essentially that of the single-stage preamp of figure 1, except the maximum gain is about 5 dB lower. A switchable 2nd stage with 20 dB of gain enables a choice of single-stage operation up to 40 dB of gain (including transformer step-up) 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 applications, and a variable 2nd stage would allow gain matching at any overall gain.

Offset voltage compensation can be performed on the 1st stage, as described in the single-stage preamp text. Note that the 2nd stage will have a low V_{os} because the inverting and non-inverting inputs see identical DC source resistances (10k).

SOCKETS

Many types of sockets are available from several manufacturers. A common socket is shown in figure 5, reprinted from the Concord catalog. The same part is available from Cambion 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 swaged (special tool required).

CONCORD ELECTRONICS CORP. (212) 777-6571
30 Great Jones St.
New York, NY 10012 Part #09-9035-2-02

CAMBION (617) 491-5400
445 Concord Ave.
Cambridge, MA 02238 Part #450-3755-02-03

A good selection of sockets is also available from:

ROBINSON NUGENT INC. (812) 945-0211
800 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 3 is attenuated by a potentiometer (typically 10 dB of attenuation) just before it enters the summing circuit. To restore the 10 dB lost through the pot, a lower value is used for R_{in}, in this case 3.16k (see formulas). With many channels being summed simultaneously, the overall composite signal at the output of the summing amp could become excessive, resulting in insufficient headroom. The final value for R_{in} would therefore be chosen based on the number of channels, signal levels, pot settings, etc.

The non-inverting input may be grounded directly, or through a resistor. The value of the 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_{in} and R_{fb}). With both inputs of the 990 seeing identical DC source resistances, the output offset voltage will be the lowest. This resistor can result in increased noise when compared 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 DC, so the terminating resistor is the only factor as far as DC specs are concerned. The impedance of the capacitor becomes much lower than that of the terminating resistor above DC, 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 channels being summed, etc. A value of 0.1 uF would be a place to start.

Note that the actual termination point or location for the non-inverting input is critical. In larger consoles with many inputs, there can be much noise appearing on 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 currents (thus voltages) from other modules, etc. Although each input of the summing amp may be 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_{in} in the gain formula. For example, 24 inputs with R_{in} of 10k results in a final parallel resistance of 417 ohms, for a voltage gain of 24 (27.6 dB). That is how much the ground bus noise would be amplified if the non-inverting input were terminated far from the signal sources being summed. Grounding is critical!

Larger summing busses cause increasing amounts of stray capacitance to appear at the inverting input. This capacitance causes phase-shift in the feedback signal, and in sufficient quantities, can cause oscillation. Additional capacitance can be used in the feedback loop to compensate. Also an isolator (normally used at the output of the 990) could be inserted between the summing bus and the inverting input, with the isolator as close to the inverting input as possible. The isolator has an impedance of 0.2 ohms at DC, rising to only 5 ohms at 20 kHz, so the audio bandwidth passes through relatively unaffected. Above 159 kHz, the impedance is 35 ohms, reducing the effects of the stray capacitance.

JE-990-4

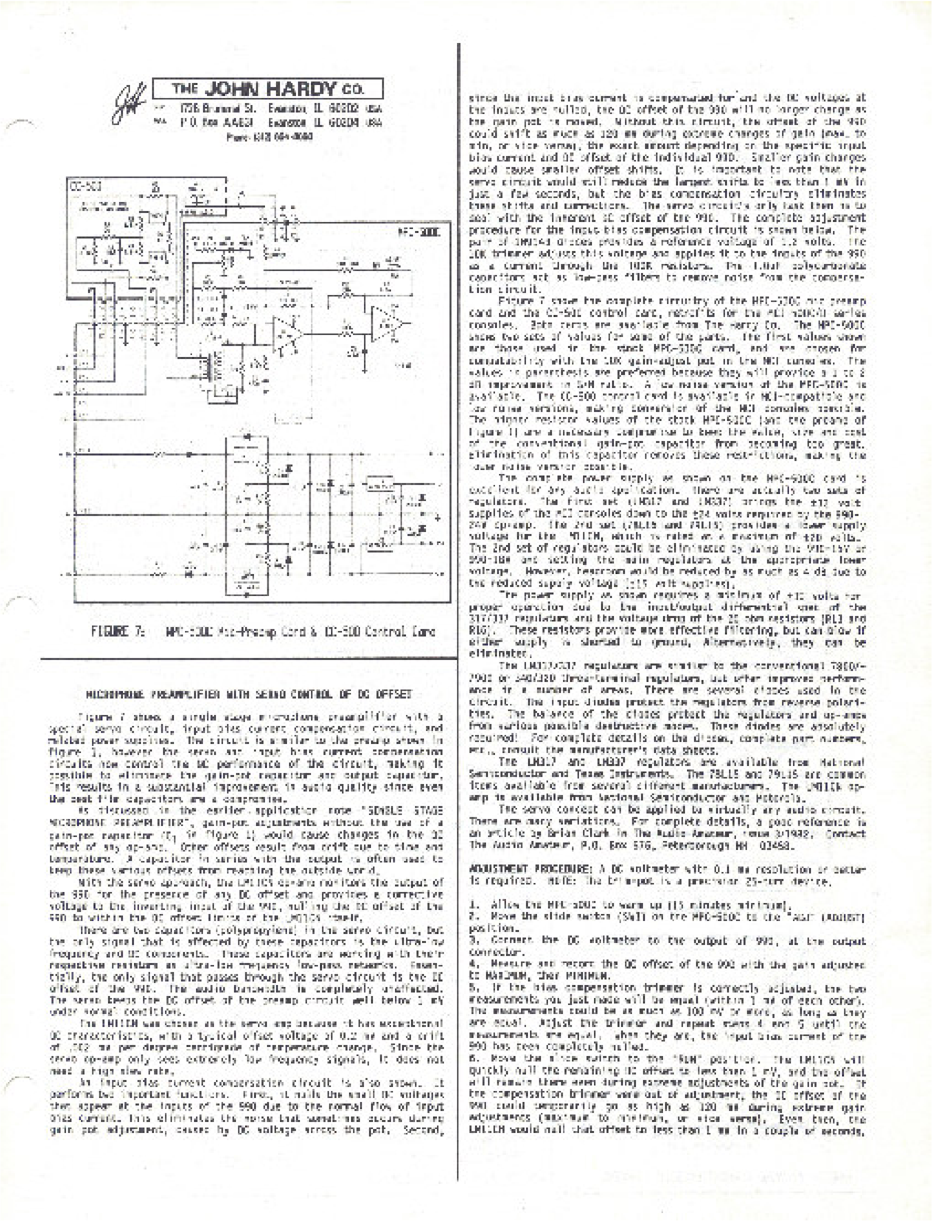


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FIGURE 7: MPC-500C Mic-Preamp Card & CC-500 Control Card

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 related power supplies. The circuit is similar to the preamp shown in figure 1, however the servo and input bias current compensation circuits now control the DC performance of the circuit, making it possible to eliminate the gain-pot capacitor 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-pot adjustments without the use of a gain-pot capacitor (C_1 in figure 1) would cause changes in the DC offset of any op-amp. Other 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 LM11CN op-amp monitors 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 to within the DC offset limits of the LM11CN itself.

There are two capacitors (polypropylene) 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 ultra-low frequency low-pass networks. 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 LM11CN 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 .002 mV per degree centigrade of temperature change. Since the servo op-amp 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 sometimes occurs during gain pot 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 nulled, 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 shift as much as 120 mV during extreme changes of gain (max. to min. or vice versa), the exact amount depending on the specific input bias current and DC offset of the individual 990. Smaller gain changes would cause smaller offset shifts. It is important to note that the servo circuit would still reduce the largest shifts to less than 1 mV in just a few seconds, but the bias compensation circuitry eliminates these shifts and corrections. 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 pair of 1N4148 diodes provides a reference voltage of 1.2 volts. The 10K trimmer adjusts this voltage and applies it to the inputs of the 990 as a current through the 100K resistors. The 1.0uF polycarbonate capacitors act as low-pass filters to remove noise from the compensation circuit.

Figure 7 shows the complete circuitry of the MPC-500C mic preamp card and the CC-500 control card, retrofits for the MCI 500C/D series consoles. Both cards are available from The Hardy Co. The MPC-500C shows two sets of values for some of the parts. The first values shown are those used in the stock MPC-500C card, and are chosen for compatability with the 10K gain-adjust pot in the MCI consoles. The values in parenthesis are preferred because they will provide a 1 to 2 dB improvement in S/N ratio. A low noise version of the MPC-500C is available. The CC-500 control card is available in MCI-compatible and low noise versions, making conversion of the MCI consoles possible. The higher resistor values of the stock MPC-500C (and the preamp of figure 1) are a necessary compromise to keep the value, size and cost of the conventional gain-pot capacitor from becoming too great. Elimination of this capacitor removes these restrictions, making the lower noise version possible.

The complete power supply as shown on the MPC-500C card is excellent for any audio application. There are actually two sets of regulators. The first set (LM317 and LM337) brings the ±32 volt supplies of the MCI consoles down to the ±24 volts required by the 990-24V op-amp. The 2nd set (78L15 and 79L15) provides a lower supply voltage for the LM11CN, which is rated at a maximum of ±20 volts. The 2nd set of regulators could be eliminated by using the 990-15V or 990-18V 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 (±15 volt supplies).

The power supply as shown requires a minimum of ±30 volts for proper operation due to the input/output differential spec of the 317/337 regulators and the voltage drop of the 20 ohm resistors (R13 and R16). These resistors provide more effective filtering, but can blow if either supply is shorted to ground. Alternatively, they can be eliminated.

The LM317/337 regulators are similar to the conventional 7800/7900 or 340/320 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 modes. These diodes are absolutely required! For complete details on the diodes, complete part numbers, etc., consult the manufacturer's data sheets.

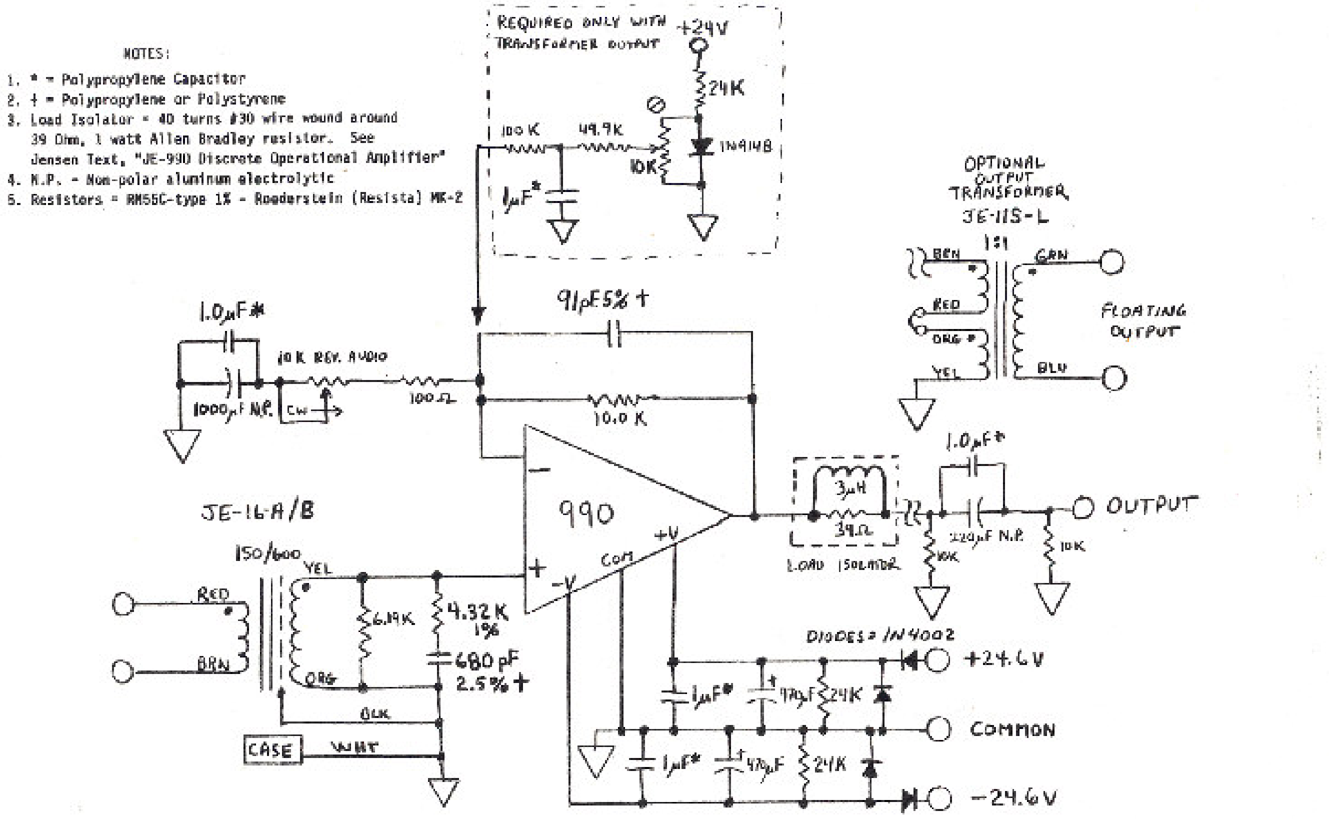
The LM317 and LM337 regulators are available from National Semiconductor and Texas Instruments. The 78L15 and 79L15 are common items available from several different manufacturers. The LM11CN op-amp is available from National Semiconductor and Motorola.

The servo concept 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 03458.

ADJUSTMENT PROCEDURE: A DC voltmeter with 0.1 mV resolution or better is required. NOTE: The trimpot is a precision 25-turn device.

1. Allow the MPC-500C to warm up (15 minutes minimum).
2. Move the slide switch (SW1) on the MPC-500C to the "ADJ" (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 gain adjusted to MAXIMUM, then 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 nulled.
6. Move the slide switch to the "RUN" position. The LM11CN will quickly null the remaining DC offset to less than 1 mV, and the offset will remain there even during extreme 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 120 mV during extreme gain adjustments (maximum to minimum, or vice versa). Even then, the LM11CN would null that offset to less than 1 mV in a couple of seconds.

JE-990-5



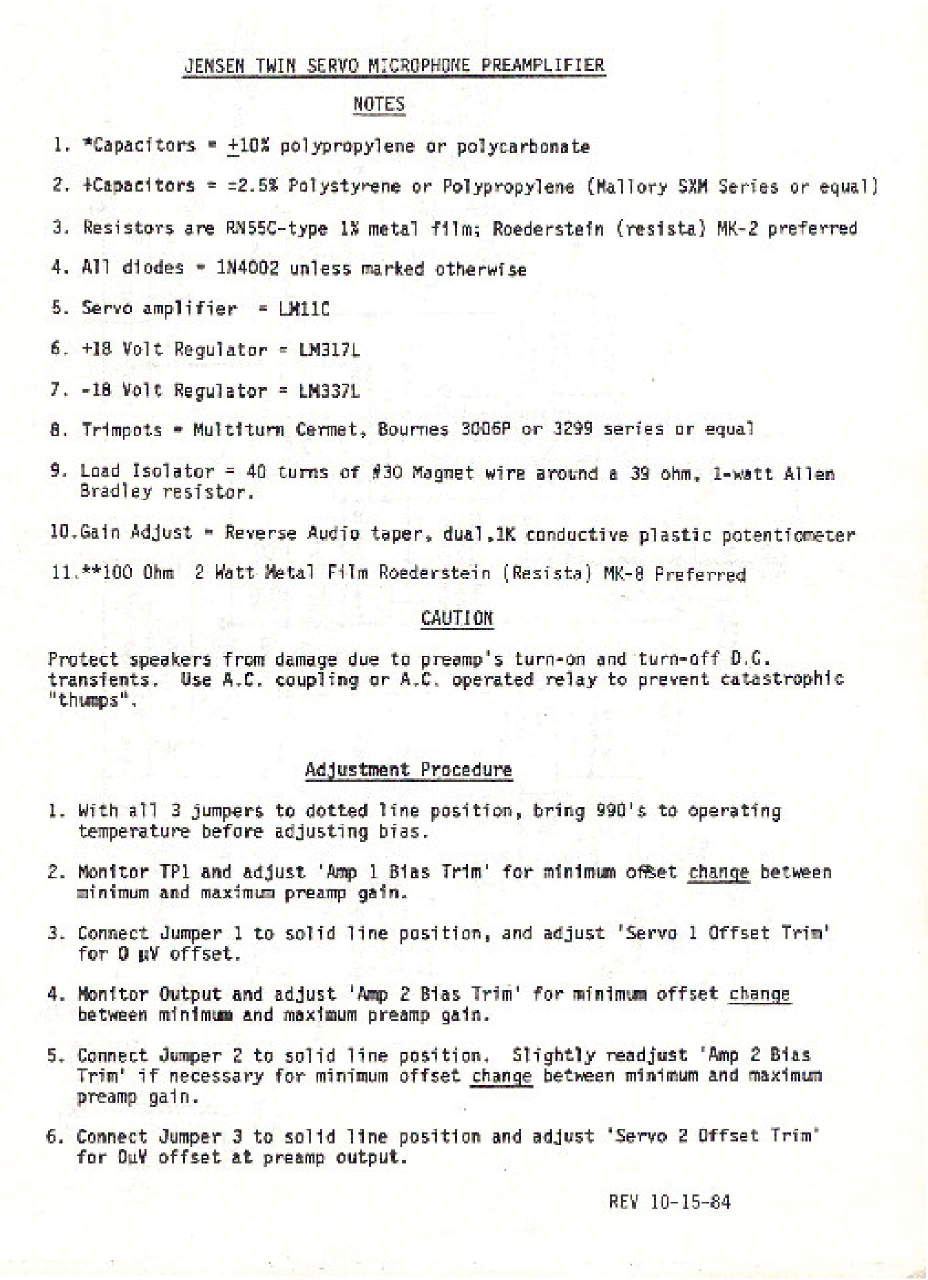
NOTES:

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 = RN55C-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 PREAMPLIFIER

NOTES

1. *Capacitors = ±10% polypropylene or polycarbonate
2. ‡Capacitors = =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, Bournes 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 µV 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 0uV offset at preamp output.

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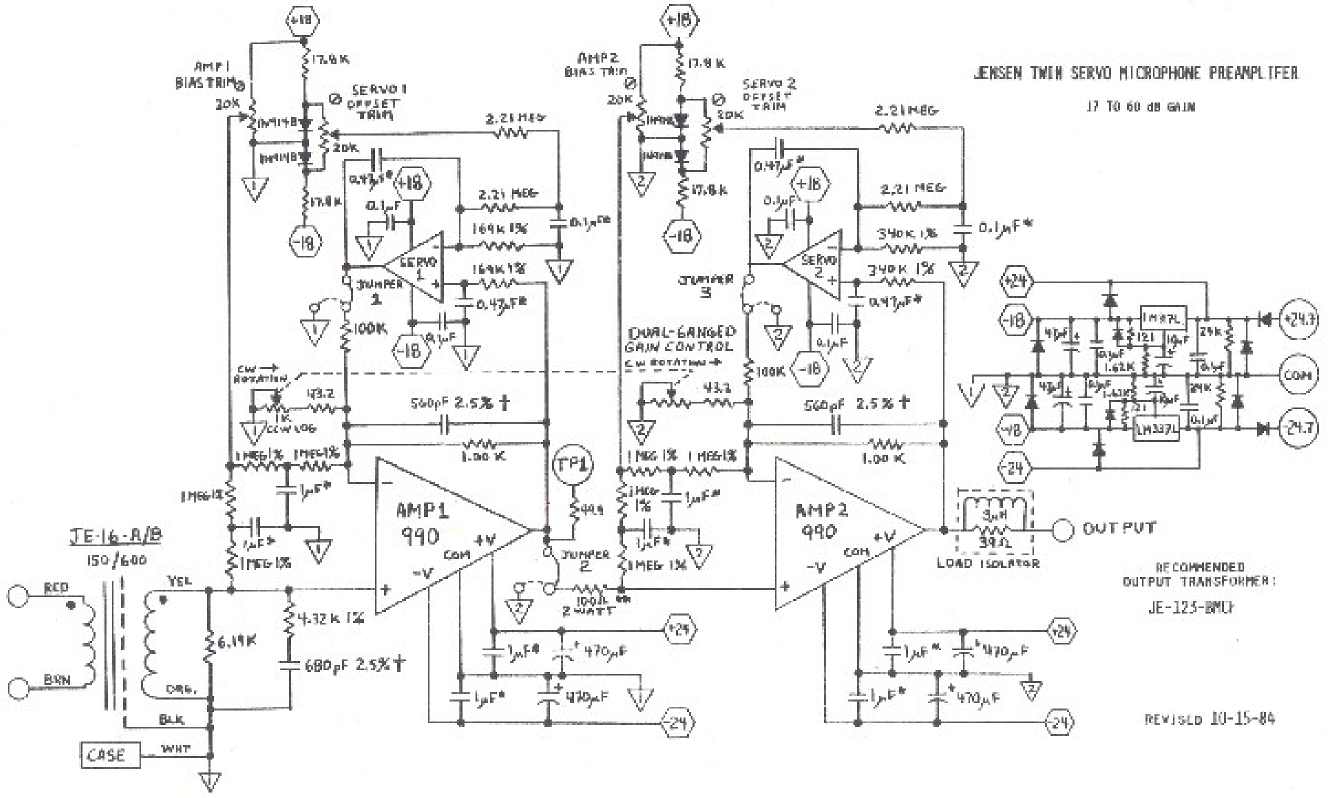
JE-990-7



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