

## LM832 Dynamic Noise Reduction System DNR®

### General Description

The LM832 is a stereo noise reduction circuit for use with audio playback systems. The DNR system is noncomplementary, meaning it does not require encoded source material. The system is compatible with virtually all prerecorded tapes and FM broadcasts. Psychoacoustic masking, and an adaptive bandwidth scheme allow the DNR to achieve 10 dB of noise reduction. DNR can save circuit board space and cost because of the few additional components required.

The LM832 is optimized for low voltage operation with input levels around 30 mVrms.

For higher input levels use the LM1894.

### Features

- Low voltage battery operation
- Non-complementary noise reduction, "single ended"
- Low cost external components, no critical matching
- Compatible with all prerecorded tapes and FM
- 10 dB effective tape noise reduction CCIR/ARM weighted
- Wide supply range, 1.5V to 9V
- 150 mVrms input overload
- No royalty requirements
- Cascade connection for 17 dB noise reduction

### Applications

- Headphone stereo
- Microcassette players
- Radio cassette players
- Automotive radio/tape players

The DNR® system is licensed to National Semiconductor Corp. under U.S. patent 3,678,416 and 3,753,159.  
A trademark and licensing agreement is required for the use of this product.

### Application Circuit

Order Number LM832M See NS Package M14A

Order Number LM832N See NS Package N14A

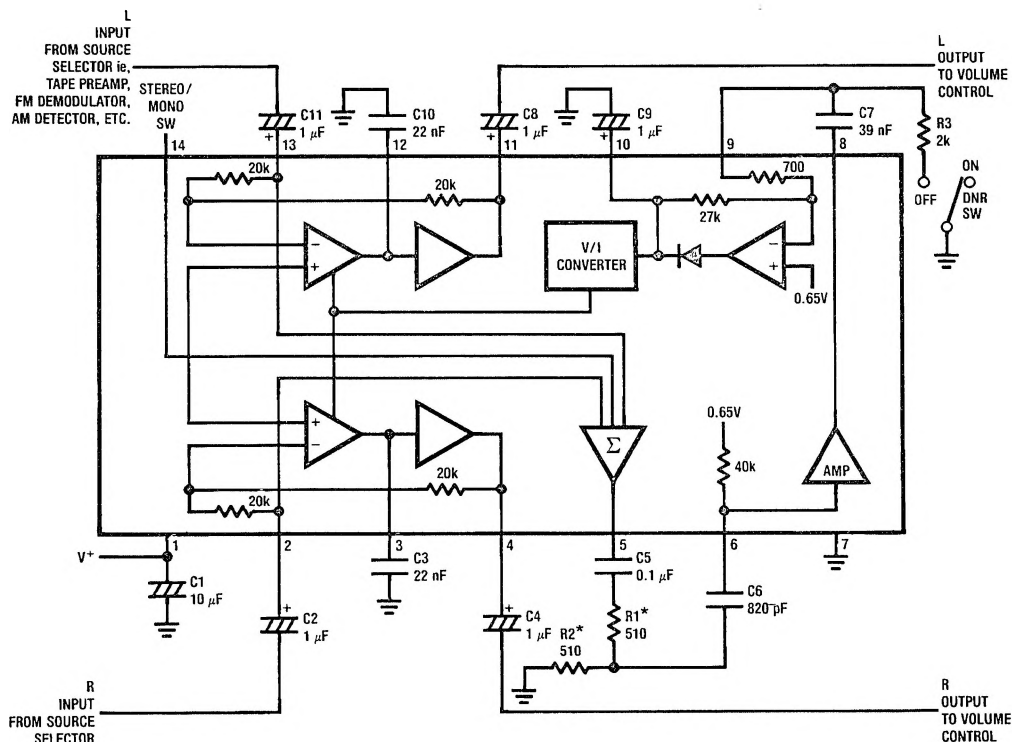


FIGURE 1. Component Hook-up for Stereo DNR System

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## Absolute Maximum Ratings

If Military/Aerospace specified devices are required, contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	10V
Power Dissipation (Note 1)	1.2W
Input Voltage	1.7 Vpp
Storage Temperature	−65 to +150°C
Operating Temperature (Note 1)	−40 to +85°

### Soldering Information

■ Dual-In-Line Package	Soldering (10 seconds)	260°C
■ Small Outline Package	Vapor Phase (60 seconds)	215°C
	Infrared (15 seconds)	220°C

See AN-450 "Surface Mounting Methods and Their Effects on Products Reliability" for other methods of soldering surface mount devices."

## DC Electrical Characteristics $T_A = 25^\circ\text{C}$ $V_{CC} = 3.0\text{V}$

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{OP}$	Operating Voltage	Supply Voltage for Normal Operation	1.5	3.0	9.0	V
$I_{CC}(1)$	Supply Current (1)	Pin 9 to GND 0.1 $\mu\text{F}$ , BW = Min, Note 2		2.5	4.0	mA
$I_{CC}(2)$	Supply Current (2)	DC GND Pin 9 with 2k, BW = Max, Note 2		5.0	8.0	mA
$V_{IN}(1)$	Input Voltage (1)	Pin 2, Pin 13	0.20	0.36	0.5	V
$V_{IN}(2)$	Input Voltage (2)	Pin 6	0.50	0.65	0.8	V
$V_{IN}(3)$	Input Voltage (3)	Pin 9	0.50	0.65	0.8	V
$V_{OUT}(1)$	Output Voltage (1)	Pin 4, Pin 11	0.20	0.35	0.50	V
$V_{OUT}(2)$	Output Voltage (2)	Pin 5 Stereo Mode	0.15	0.28	0.40	V
$V_{OUT}(3)$	Output Voltage (3)	Pin 5 Monaural Mode, DC Ground Pin 14	0.10	0.20	0.30	V
$V_{OUT}(4)$	Output Voltage (4)	Pin 8	0.25	0.40	0.60	V
$V_{OUT}(5)$	Output Voltage (5)	Pin 10 BW = Max, Note 2	1.00	1.27	1.50	V
$V_{OUT}(6)$	Output Voltage (6)	Pin 10 BW = Min, Note 2	0.50	0.65	0.75	V
$V_{OS}$	Output DC Shift	Pin 4, PIN 11; Change BW Min to Max		1.0	3.0	mV

## AC Electrical Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
<b>MAIN SIGNAL PATH (Note 3)</b>						
$A_V$	Voltage Gain	$V_{IN} = 30\text{ mVrms}$ , $f = 1\text{ kHz}$ , BW = Max, Note 2	−1.0	0.0	+1.0	dB
C.B.	Channel Balance	$V_{IN} = 30\text{ mVrms}$ , $f = 1\text{ kHz}$ , BW = Max, Note 2	−1.0	0	+1.0	dB
$f_{MIN}$	Min Bandwidth	0.1 $\mu\text{F}$ between Pin 9 - GND	600	1000	1500	Hz
$f_{MAX}$	Max Bandwidth	DC Ground Pin 9 with 2k	24	30	46	kHz
THD	Distortion	$V_{IN} = 30\text{ mVrms}$ , $f = 1\text{ kHz}$ , BW = Max, Note 2		0.07	0.5	%
$MV_{IN}$	Max Input Voltage	THD = 3%, $f = 1\text{ kHz}$ , BW = Max Note 2	120	150		mVrms
S/N	Signal to Noise	REF = 30 mVrms, BW = Max, CCIR/ARM	60	68		dB
$Z_{IN}$	Input Impedance	Pin 2, Pin 13	14	20	26	k $\Omega$
C.S.	Channel Separation	Ref = 30 mVrms, $f = 1\text{ kHz}$ , BW = Max, Note 2	40	68		dB
$P_{SRR}$	$P_{SRR}$	$V_{RIPPLE} = 50\text{ mVrms}$ , $f = 100\text{ Hz}$	40	55		dB
<b>CONTROL PATH</b>						
$A_{Vsum}(1)$	Summing Amp Gain (1)	$V_{IN} = 30\text{ mVrms}$ at R and L, $f = 1\text{ kHz}$	−3.0	−1.5	0.0	dB
$A_{Vsum}(2)$	Summing Amp Gain (2)	DC Ground Pin 14, $f = 1\text{ kHz}$	−9.0	−6.0	−3.0	dB
$A_V$ 1st	Gain Amp Gain	Pin 6 to Pin 8	25	30	35	dB
$Z_{IN}$ 1st	Input Impedance	Pin 6	28	40	52	k $\Omega$
$A_{VPKD}$	Peak Detector Gain	AC In, DC Out; Pin 9 to Pin 10	25	30	35	V/V
$Z_{INPKD}$	Input Impedance	Pin 9	500	800	1100	$\Omega$
$V_{RPKD}$	Output DC Change	Pin 10, Change BW Min to Max	0.5	0.62	0.8	V

**Note 1:** For operation in ambient temperature above 25°C, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance junction to ambient, as follows: LM832N −90° c/w, LM832M-115° c/w.

**Note 2:** To force the DNR system into maximum bandwidth, connect a 2k resistor from pin 9 to GND. AC ground pin 9 or pin 6 to select minimum bandwidth. To change minimum and maximum bandwidth, see Application Hints.

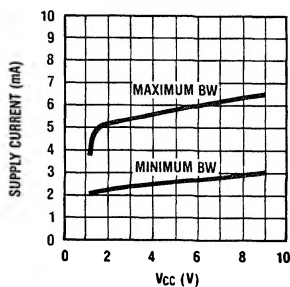
**Note 3:** The maximum noise reduction CCIR/ARM weighted is about 14 dB. This is accomplished by changing the bandwidth from maximum to minimum. In actual operation, minimum bandwidth is not selected, a nominal minimum bandwidth of about 2 kHz gives 10 dB of noise reduction. See Application Hints.

## External Component Guide (See Figure 1)

P/N	Recommended Value	Purpose	Effect		Remarks
			Smaller	Larger	
C1	10 $\mu$ F	Power supply decoupling	Poor supply rejection	Better supply rejection	Do not use less than 10 $\mu$ F
C2,C11	1 $\mu$ F	Input coupling capacitor	Increases frequency of low-frequency roll-off	Reduces frequency of low-frequency roll-off	DC voltage at pin 2 and pin 13 is 0.35V $f = \frac{1}{2\pi C_2 R_{IN}}$
C3,C10	22 nF for Stereo, 15 nF for mono	Establishment of Min and Max Bandwidth	Bandwidth becomes wider	Bandwidth becomes narrower	See Note 4
C4,C8	1 $\mu$ F	Output coupling capacitor	Increases frequency of low-frequency roll-off	Reduces frequency of low-frequency roll-off	DC voltage at pin 4 and pin 11 is 0.35V $f = \frac{1}{2\pi C_4 R_{LOAD}}$
C5	0.1 $\mu$ F	Works with R1 and R2 to set one of the low-frequency corners in control path	Some high frequency program material may be attenuated	Bandwidth may increase due to low-frequency inputs, causing "Breathing"	$f = \frac{1}{2\pi C_5 (R_1 + R_2)} = 1.6 \text{ kHz}$ See Note 4
C6	820 pF	Works with input resistance of pin 6 to set one of the low-frequency corners in the control path	Same as above	Same as above	$f = \frac{1}{2\pi C_6 R_{PIN6}} = 4.8 \text{ kHz}$ See Note 4
C7	39 nF	Works with input resistance of pin 9 to form part of control path frequency weighing	Same as above	Same as above	$f = \frac{1}{2\pi C_7 R_{PIN7}} = 4.8 \text{ kHz}$ See Note 4
C9	1 $\mu$ F	Sets attack time	Reduces attack and decay time	Increases attack and decay time	See Note 4
R1,R2	$R_1 + R_2 = 1 \text{ k}\Omega$	This voltage divider sets control path sensitivity	—	—	Sensitivity should be set for maximum noise reduction and minimum audible frequency program effect on high
R3	$\bullet 2 \text{ k}\Omega$	Sets gain amp load when DNR is OFF	Loads gain amp output, may cause distortion	Max bandwidth will be reduced	

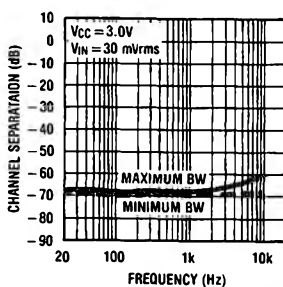
**Note 4:** The values of the control path filter components (C5, C6, C7, C9, R1, R2) and the integrating capacitors (C3, C10) should not be changed from the recommended values unless the characteristics of the noise or program material differ substantially from that of FM or tape sources. Failure to use the correct values may result in degraded performance, and therefore the application may not be approved for DNR trademark usage. Please contact National Semiconductor for more information and technical assistance.

# Typical Performance Characteristics



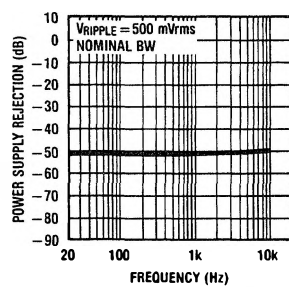
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**FIGURE 2. Supply current vs supply voltage**



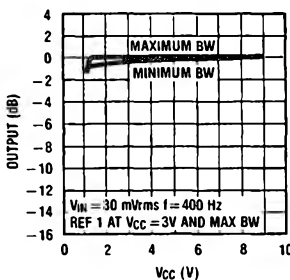
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**FIGURE 3. Channel separation vs frequency**



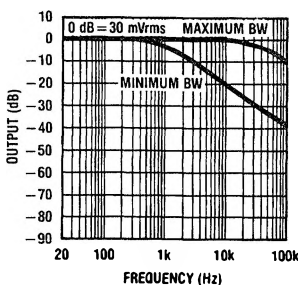
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**FIGURE 4. Power supply rejection ratio vs frequency**



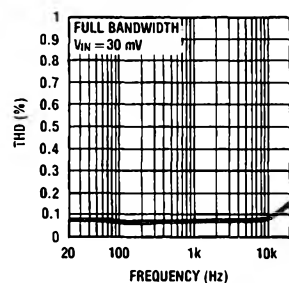
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**FIGURE 5. Output level change vs supply voltage**



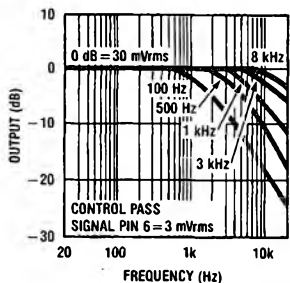
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**FIGURE 6. Output level vs frequency**



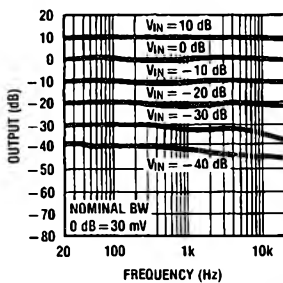
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**FIGURE 7. THD vs frequency**



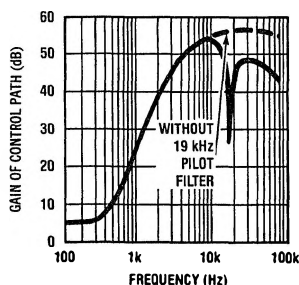
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**FIGURE 8. Output vs frequency and control path signal**



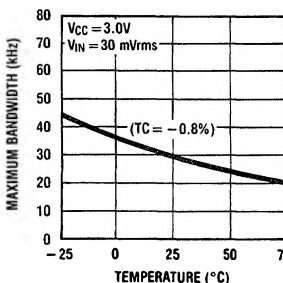
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**FIGURE 9. Frequency response for various input levels**



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**FIGURE 10. Gain of control path vs frequency**



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**FIGURE 11. Change in main signal path maximum bandwidth vs temperature**

## Circuit Operation

The LM832 has two signal paths, a main signal path and a bandwidth control path. The main path is an audio low pass filter comprised of a  $g_m$  block with a variable current, and a unity gain buffer. As seen in *Figure 1*, DC feedback constrains the low frequency gain to  $A_v = -1$ . Above the cutoff frequency of the filter, the output decreases at  $-6$  dB/oct due to the action of the  $0.022 \mu\text{F}$  capacitor.

The purpose of the control path is to generate a bandwidth control signal which replicates the ear's sensitivity to noise in the presence of a tone. A single control path is used for both channels to keep the stereo image from wandering. This is done by adding the right and left channels together in the summing amplifier of *Figure 1*. The R1, R2 resistor divider adjusts the incoming noise level to slightly open the bandwidth of the low pass filter. Control path gain is about 60dB and is set by the gain amplifier and peak detector gain. This large gain is needed to ensure the low pass filter bandwidth can be opened by very low noise floors. The capacitors between the summing amplifier output and the peak detector input determine the frequency weighting as shown in the typical performance curves. The  $1 \mu\text{F}$  capacitor at pin 10, in conjunction with internal resistors, sets the attack and decay times. The voltage is converted into a proportional current which is fed into the  $g_m$  blocks. The bandwidth sensitivity to  $g_m$  current is  $70 \text{ Hz}/\mu\text{A}$ . In FM stereo applications a 19 kHz pilot filter is inserted between pin 8 and pin 9 as shown in *Figure 16*.

Normal methods of evaluating the frequency response of the LM 832 can be misleading if the input signal is also applied to the control path. Since the control path includes a frequency weighting network, a constant amplitude but varying frequency input signal will change the audio signal path bandwidth in a non-linear fashion. Measurements of the audio signal path frequency response will therefore be in error since the bandwidth will be changing during the measurement. See *Figure 9* for an example of the misleading results that can be obtained from this measurement approach. Although the frequency response is always flat below a single high-frequency pole, the lower curves do not resemble single pole responses at all.

A more accurate evaluation of the frequency response can be seen in *Figure 8*. In this case the main signal path is frequency swept while, the control path has a constant frequency applied. It can be seen that different control path frequencies each give a distinctive gain roll-off.

## PSYCHOACOUSTIC BASICS

The dynamic noise reduction system is a low pass filter that has a variable bandwidth of 1 kHz to 30 kHz, dependent on music spectrum. The DNR system operates on three principles of psychoacoustics.

1. Music and speech can mask noise. In the absence of source material, background noise can be very audible. However, when music or speech is present, the human ear is less able to distinguish the noise—the source material is said to mask the noise. The degree of masking is dependent on the amplitude and spectral content (frequencies) of the source material, but in general multiple tones around 1 kHz are capable of providing excellent masking of noise over a very wide frequency range.
2. The ear cannot detect distortion for less than 1 ms. On a transient basis, if distortion occurs in less than 1 ms, the ear

acts as an integrator and is unable to detect it. Because of this, signals of sufficient energy to mask noise open the bandwidth to 90% of the maximum value in less than 1 ms. Reducing the bandwidth to within 10% of its minimum value is done in about 60 ms: long enough to allow the ambience of the music to pass through, but not so long as to allow the noise floor to become audible.

3. Reducing the audio bandwidth reduces the audibility of noise. Audibility of noise is dependent on noise spectrum, or how the noise energy is distributed with frequency. Depending on the tape and the recorder equalization, tape noise spectrum may be slightly rolled off with frequency on a per octave basis. The ear sensitivity on the other hand greatly increases between 2 kHz and 10 kHz. Noise in this region is extremely audible. The DNR system low pass filters this noise. Low frequency music will not appreciably open the DNR bandwidth, thus 2 kHz to 20 kHz noise is not heard.

## Application Hints

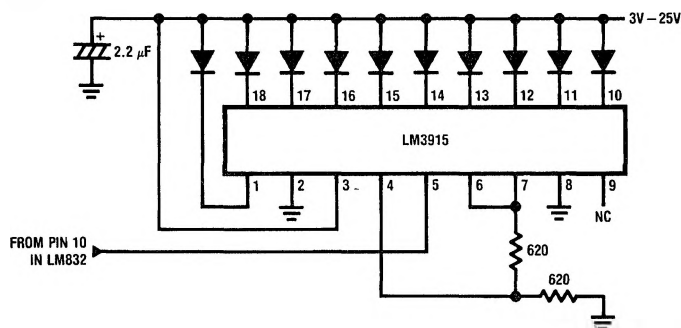
The DNR system should always be placed before tone and volume controls as shown in *Figure 1*. This is because any adjustment of these controls would alter the noise floor seen by the DNR control path. The sensitivity resistors R1 and R2 may need to be switched with the input selector, depending on the noise floors of different sources, i.e., tape, FM, phono. To determine the value of R1 and R2 in a tape system for instance; apply tape noise (no program material) and adjust the ratio of R1 and R2 to slightly open the bandwidth of the main signal path. This can easily be done by viewing the capacitor voltage of pin 10 with an oscilloscope, or by using the circuit of *Figure 12*. This circuit gives an LED display of the voltage on the peak detector capacitor. Adjust the values of R1 and R2 (their sum is always 1 k $\Omega$ ) to light the LEDs of pin 1 and pin 18. The LED bar graph does not indicate signal level, but rather instantaneous bandwidth of the two filters; it should not be used as a signal-level indicator. For greater flexibility in setting the bandwidth sensitivity, R1 and R2 could be replaced by a 1 k $\Omega$  potentiometer.

To change the minimum and maximum value of bandwidth, the integrating capacitors, C3 and C10, can be scaled up or down. Since the bandwidth is inversely proportional to the capacitance, changing this  $0.022 \mu\text{F}$  capacitor to  $0.015 \mu\text{F}$  will change the typical bandwidth from 1 kHz–30 kHz to 1.5 kHz–44 kHz. With C3 and C10 set at  $0.022 \mu\text{F}$ , the maximum bandwidth is typically 30 kHz. A double pole double throw switch can be used to completely bypass DNR.

The capacitor on pin 10 in conjunction with internal resistors sets the attack and decay times. The attack time can be altered by changing the size of C9. Decay times can be decreased by paralleling a resistor with C9, and increased by increasing the value of C9.

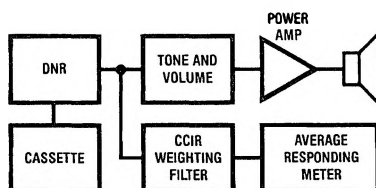
When measuring the amount of noise reduction of DNR in a cassette tape system, the frequency response of the cassette should be flat to 10 kHz. The CCIR weighting network has substantial gain to 8 kHz and any additional roll-off in the cassette player will reduce the benefits of DNR noise reduction. A typical signal-to-noise measurement circuit is shown in *Figure 13*. The DNR system should be switched from maximum bandwidth to nominal bandwidth with tape noise as a signal source. The reduction in measured noise is the signal-to-noise ratio improvement.

## Application Hints (Continued)



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FIGURE 12. Bar Graph Display of Peak Detector Voltage



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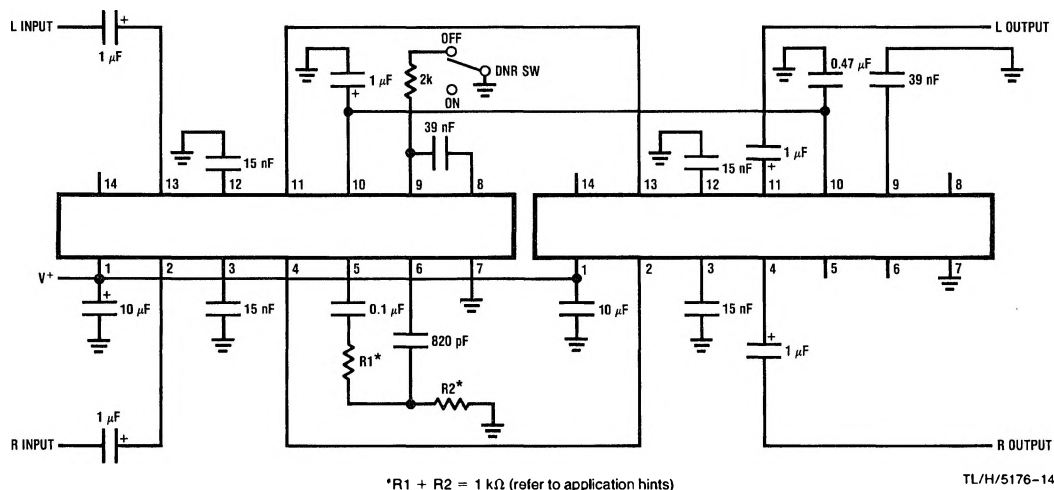
FIGURE 13. Technique for Measuring S/N Improvement of the DNR System

### CASCADE CONNECTION

Additional noise reduction can be obtained by cascading the DNR filters. With two filters cascaded the rolloff is 12 dB per octave. For proper operating bandwidth the capacitors on pin 3 and 12 are changed to 15 nF. The resulting noise reduction is about 17 dB.

Figure 15 shows the monaural cascade connection. Note that pin 14 is grounded so only the pin 2 input is fed to the summing amp and therefore the control path.

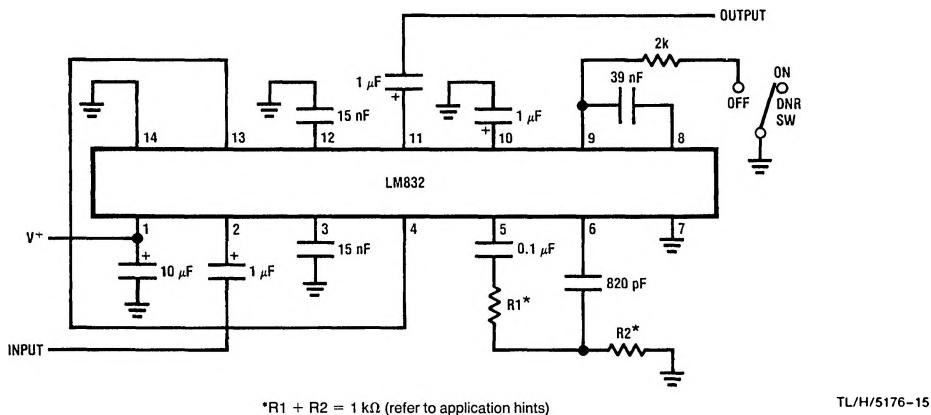
Figure 14 shows the stereo cascade connection. Note that pin 14 is open circuit as in normal stereo operation.



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FIGURE 14. Stereo Cascade Connection

## Application Hints (Continued)



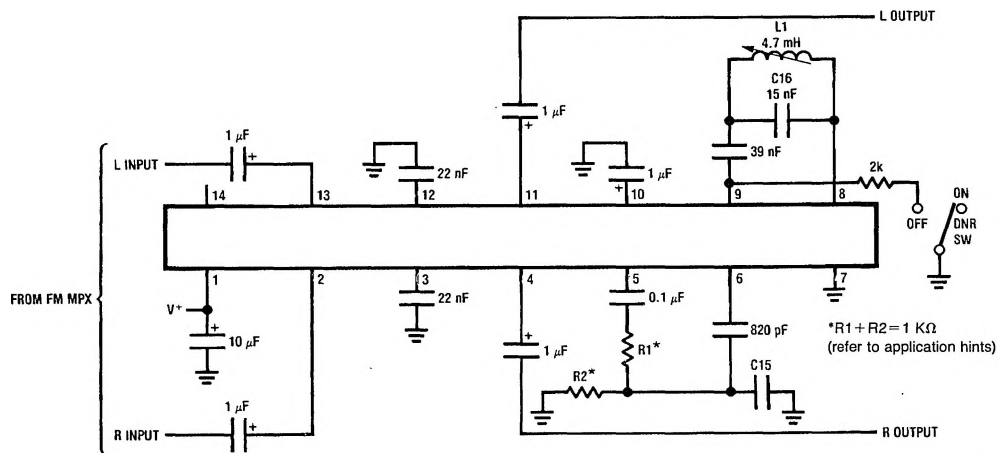
**FIGURE 15. Monaural Cascade Connection**

### FM STEREO

When using the DNR system with FM stereo as the audio source, it is important to eliminate the ultrasonic frequencies that accompany the audio. If the radio has a multiplex filter to remove the ultrasonics there will be no problem.

This filtering can be done at the output of the demodulator, before the DNR system, or in the DNR system control path.

Standard audio multiplex filters are available for use at the output of the demodulator from several filter companies. Figure 16 shows the additional components L1, C15 and C16 that are added to the control path for FM stereo applications. The coil must be tuned to 19 kHz, the FM pilot frequency.



**FIGURE 16. FM Stereo Application**

### FOR FURTHER READING

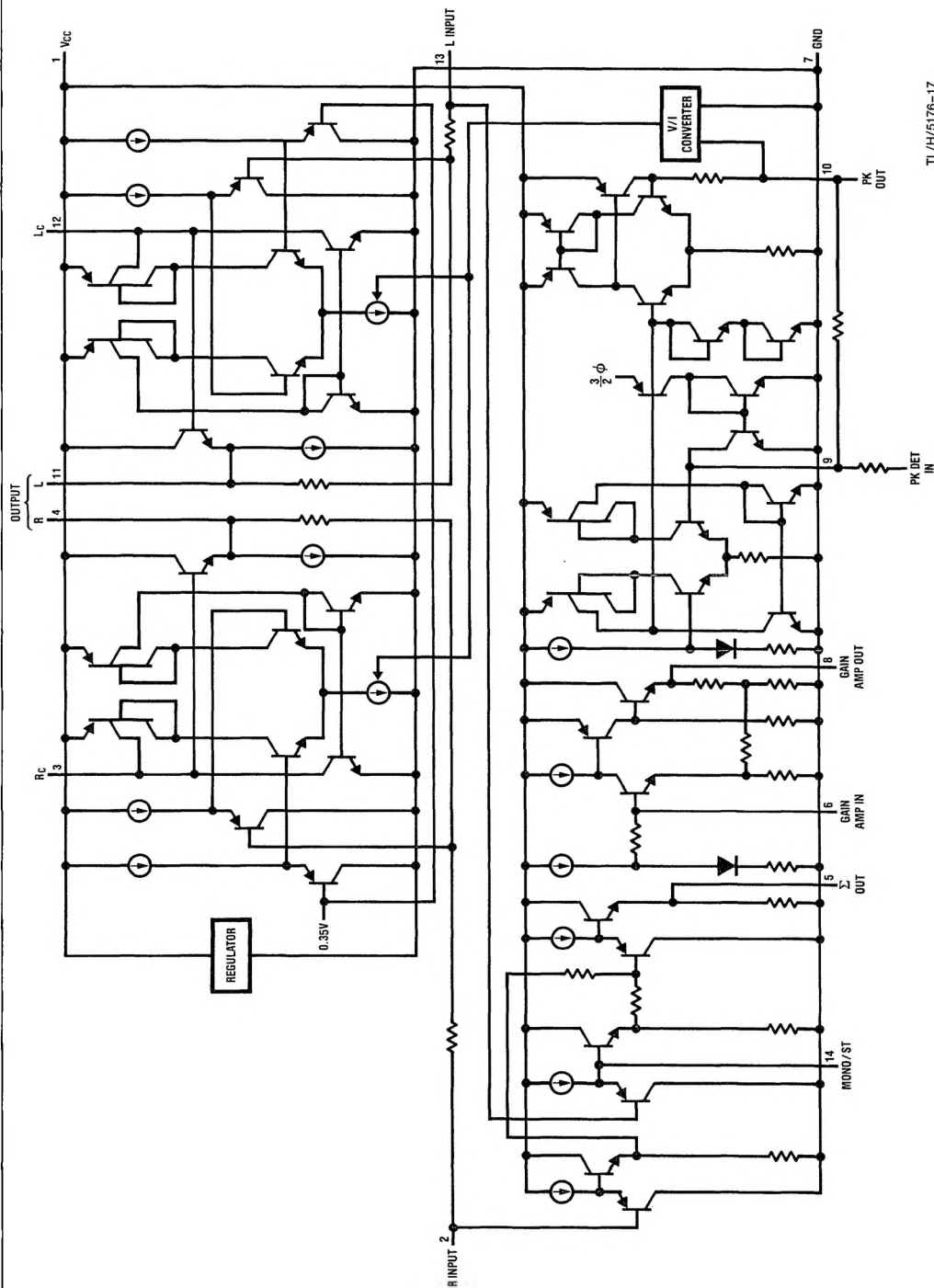
#### Tape Noise Levels

1. "A Wide Range Dynamic Noise Reduction System" Blackmer, 'dB' Magazine, August-September 1972, Volume 6, #8.
2. "Dolby B-Type Noise Reduction System", Berkowitz and Gundry, Sert Journal, May-June 1974, Volume 8.
3. "Cassette vs Elcaset vs Open Reel", Toole, Audioscene Canada, April 1978.
4. "CCIR/ARM: A Practical Noise Measurement Method", Dolby, Robinson, Gundry, JAES, 1978.

#### Noise Masking

1. "Masking and Discrimination", Bos and De Boer, JAES, Volume 39, #4, 1966.
2. "The Masking of Pure Tones and Speech by White Noise", Hawkins and Stevens, JAES, Volume 22, #1, 1950.
3. "Sound System Engineering", Davis, Howard W. Sams and Co.
4. "High Quality Sound Reproduction", Moir, Chapman Hall, 1960.
5. "Speech and Hearing in Communication", Fletcher, Van Nostrand, 1953.

## LM832 Simple Circuit Schematic



TL/H/5176-17