

## LM1894

### Dynamic Noise Reduction System DNR®

#### General Description

The LM1894 is a stereo noise reduction circuit for use with audio playback systems. The DNR system is non-complementary, 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.

#### Features

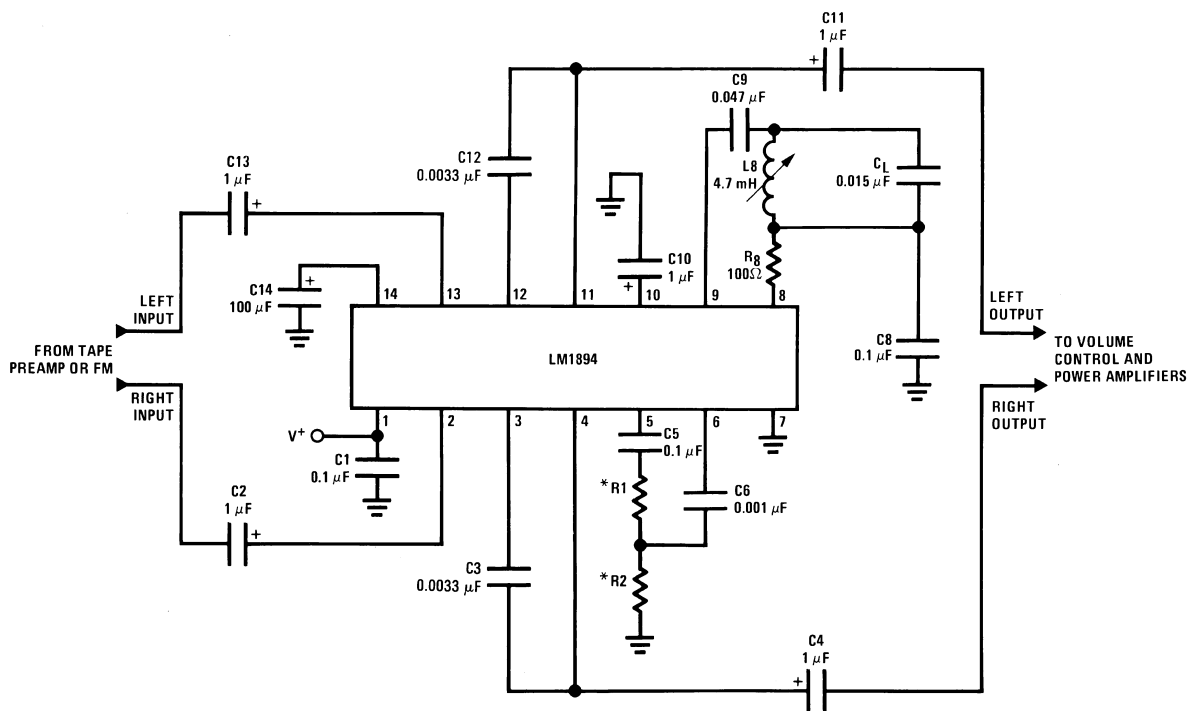
- Non-complementary noise reduction, "single ended"
- Low cost external components, no critical matching

- Compatible with all prerecorded tapes and FM
- 10 dB effective tape noise reduction CCIR/ARM weighted
- Wide supply range, 4.5V to 18V
- 1 Vrms input overload

#### Applications

- Automotive radio/tape players
- Compact portable tape players
- Quality HI-FI tape systems
- VCR playback noise reduction
- Video disc playback noise reduction

#### Typical Application



\*R1 + R2 = 1 kΩ total.  
See Application Hints.

Order Number LM1894M, LM1894N, or LM1894MT  
See NS Package Number M14A, N14A, or MTC14  
**FIGURE 1. Component Hook-Up for Stereo DNR System**

DNR® is a registered trademark of National Semiconductor Corporation.  
The DNR® system is licensed to National Semiconductor Corporation under U.S. patent 3,678,416 and 3,753,159.  
Trademark and license agreement required for use of this product.

**Absolute Maximum Ratings** (Note 1)

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

|                                |                 |
|--------------------------------|-----------------|
| Supply Voltage                 | 20V             |
| Input Voltage Range, $V_{pk}$  | $V_S/2$         |
| Operating Temperature (Note 2) | 0°C to +70°C    |
| Storage Temperature            | -65°C to +150°C |
| 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 Effect on Product Reliability" for other methods of soldering surface mount devices.

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

**Electrical Characteristics**

$V_S = 8V$ ,  $T_A = 25^\circ C$ ,  $V_{IN} = 300\text{ mV}$  at 1 kHz, circuit shown in Figure 1 unless otherwise specified

| Parameter                      | Conditions                                                                                                   | Min  | Typ         | Max  | Units      |
|--------------------------------|--------------------------------------------------------------------------------------------------------------|------|-------------|------|------------|
| Operating Supply Range         |                                                                                                              | 4.5  | 8           | 18   | V          |
| Supply Current                 | $V_S = 8V$                                                                                                   |      | 17          | 30   | mA         |
| <b>MAIN SIGNAL PATH</b>        |                                                                                                              |      |             |      |            |
| Voltage Gain                   | DC Ground Pin 9, (Note 3)                                                                                    | -0.9 | -1          | -1.1 | V/V        |
| DC Output Voltage              |                                                                                                              | 3.7  | 4.0         | 4.3  | V          |
| Channel Balance                | DC Ground Pin 9                                                                                              | -1.0 |             | 1.0  | dB         |
| Minimum Balance                | AC Ground Pin 9 with 0.1 $\mu F$ Capacitor, (Note 3)                                                         | 675  | 965         | 1400 | Hz         |
| Maximum Bandwidth              | DC Ground Pin 9, (Note 3)                                                                                    | 27   | 34          | 46   | kHz        |
| Effective Noise Reduction      | CCIR/ARM Weighted, (Note 4)                                                                                  |      | -10         | -14  | dB         |
| Total Harmonic Distortion      | DC Ground Pin 9                                                                                              |      | 0.05        | 0.1  | %          |
| Input Headroom                 | Maximum $V_{IN}$ for 3% THD<br>AC Ground Pin 9                                                               |      | 1.0         |      | Vrms       |
| Output Headroom                | Maximum $V_{OUT}$ for 3% THD<br>DC Ground Pin 9                                                              |      | $V_S - 1.5$ |      | Vp-p       |
| Signal to Noise                | BW = 20 Hz–20 kHz, re 300 mV<br>AC Ground Pin 9                                                              |      | 79          |      | dB         |
|                                | DC Ground Pin 9                                                                                              |      | 77          |      | dB         |
|                                | CCIR/ARM Weighted re 300 mV<br>(Note 5)                                                                      |      |             |      |            |
|                                | AC Ground Pin 9                                                                                              | 82   | 88          |      | dB         |
|                                | DC Ground Pin 9                                                                                              | 70   | 76          |      | dB         |
|                                | CCIR Peak, re 300 mV, (Note 6)                                                                               |      |             |      |            |
|                                | AC Ground Pin 9                                                                                              |      | 77          |      | dB         |
|                                | DC Ground Pin 9                                                                                              |      | 64          |      | dB         |
| Input Impedance                | Pin 2 and Pin 13                                                                                             | 14   | 20          | 26   | k $\Omega$ |
| Channel Separation             | DC Ground Pin 9                                                                                              | -50  | -70         |      | dB         |
| Power Supply Rejection         | C14 = 100 $\mu F$ ,<br>$V_{RIPPLE} = 500\text{ mVrms}$ ,<br>$f = 1\text{ kHz}$                               | -40  | -56         |      | dB         |
| Output DC Shift                | Reference DVM to Pin 14 and<br>Measuree Output DC Shift from<br>Minimum to Maximum Band-<br>width, (Note 7). |      | 4.0         | 20   | mV         |
| <b>CONTROL SIGNAL PATH</b>     |                                                                                                              |      |             |      |            |
| Summing Amplifier Voltage Gain | Both Channels Driven                                                                                         | 0.9  | 1           | 1.1  | V/V        |
| Gain Amplifier Input Impedance | Pin 6                                                                                                        | 24   | 30          | 39   | k $\Omega$ |
| Voltage Gain                   | Pin 6 to Pin 8                                                                                               | 21.5 | 24          | 26.5 | V/V        |

## Electrical Characteristics (Continued)

$V_S = 8V$ ,  $T_A = 25^\circ C$ ,  $V_{IN} = 300\text{ mV}$  at 1 kHz, circuit shown in *Figure 1* unless otherwise specified

| Parameter                     | Conditions                                            | Min | Typ | Max | Units    |
|-------------------------------|-------------------------------------------------------|-----|-----|-----|----------|
| <b>CONTROL SIGNAL PATH</b>    |                                                       |     |     |     |          |
| Peak Detector Input Impedance | Pin 9                                                 | 560 | 700 | 840 | $\Omega$ |
| Voltage Gain                  | Pin 9 to Pin 10                                       | 30  | 33  | 36  | V/V      |
| Attack Time                   | Measured to 90% of Final Value with 10 kHz Tone Burst | 300 | 500 | 700 | $\mu s$  |
| Decay Time                    | Measured to 90% of Final Value with 10 kHz Tone Burst | 45  | 60  | 75  | ms       |
| DC Voltage Range              | Minimum Bandwidth to Maximum Bandwidth                | 1.1 |     | 3.8 | V        |

**Note 2:** For operation in ambient temperature above  $25^\circ C$ , the device must be derated based on a  $150^\circ C$  maximum junction temperature and a thermal resistance of 1)  $80^\circ C/W$  junction to ambient for the dual-in-line package, 2)  $105^\circ C/W$  junction to ambient for the small outline package, and 3)  $150^\circ C/W$  junction to ambient for the TSSOP package.

**Note 3:** To force the DNR system into maximum bandwidth, DC ground the input to the peak detector, pin 9. A negative temperature coefficient of  $-0.5\%/^\circ C$  on the bandwidth, reduces the maximum bandwidth at increased ambient temperature or higher package dissipation. AC ground pin 9 or pin 6 to select minimum bandwidth. To change minimum and maximum bandwidth, see Application Hints.

**Note 4:** 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  $-10\text{ dB}$  of noise reduction. See Application Hints.

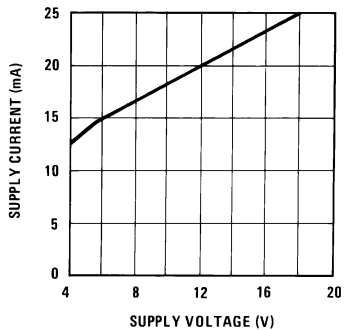
**Note 5:** The CCIR/ARM weighted noise is measured with a 40 dB gain amplifier between the DNR system and the CCIR weighting filter; it is then input referred.

**Note 6:** Measured using the Rhode-Schwartz psophometer.

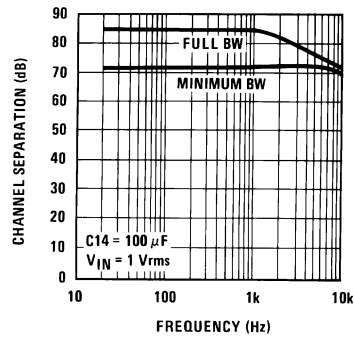
**Note 7:** Pin 10 is DC forced half way between the maximum bandwidth DC level and minimum bandwidth DC level. An AC 1 kHz signal is then applied to pin 10. Its peak-to-peak amplitude is  $V_{DC}(\text{max BW}) - V_{DC}(\text{min BW})$ .

## Typical Performance Characteristics

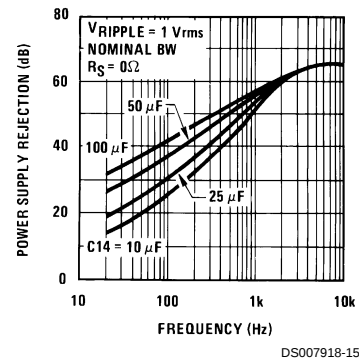
**Supply Current vs Supply Voltage**



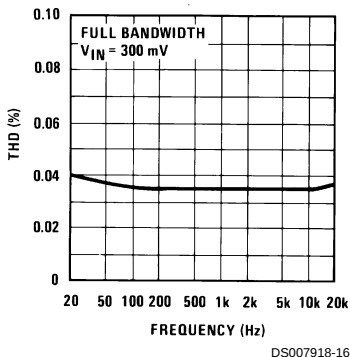
**Channel Separation (Referred to the Output) vs Frequency**



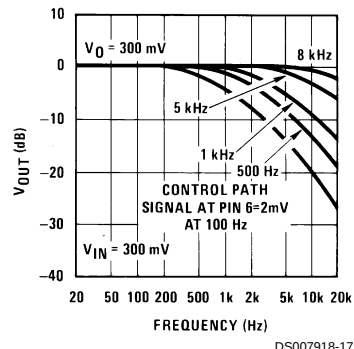
**Power Supply Rejection Ratio (Referred to the Output) vs Frequency**



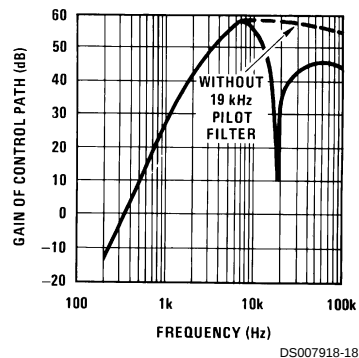
**THD vs Frequency**



**-3 dB Bandwidth vs Frequency and Control Signal**

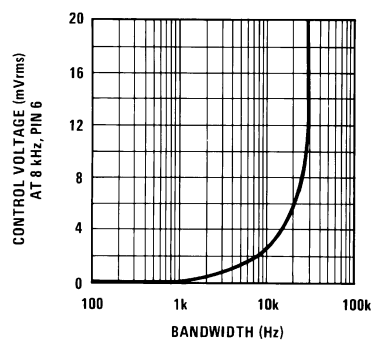


**Gain of Control Path vs Frequency (with 10 kHz FM Pilot Filter)**



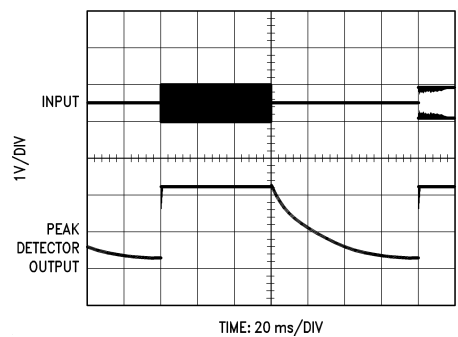
## Typical Performance Characteristics (Continued)

**Main Signal Path  
Bandwidth vs  
Voltage Control**



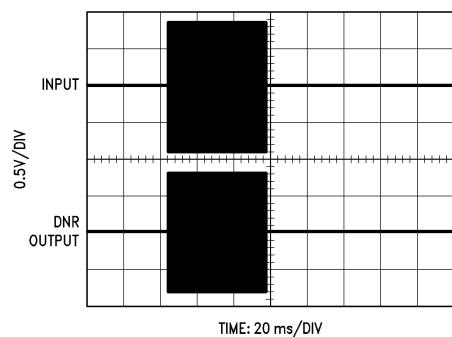
DS007918-3

**Peak Detector Response**



DS007918-4

**Output Response**



DS007918-5

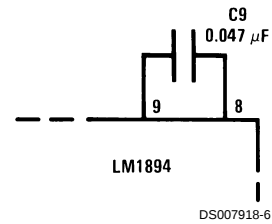
## External Component Guide

(Figure 1)

| Component | Value                       | Purpose                                                                                                                                                                                                    |
|-----------|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C1        | 0.1 $\mu$ F–<br>100 $\mu$ F | May be part of power supply, or may be added to suppress power supply oscillation.                                                                                                                         |
| C2, C13   | 1 $\mu$ F                   | Blocks DC, pin 2 and pin 13 are at DC potential of $V_S/2$ . C2, C13 form a low frequency pole with 20k $R_{IN}$ .<br>$f_L = \frac{1}{2\pi C2 R_{IN}}$                                                     |
| C14       | 25 $\mu$ F–<br>100 $\mu$ F  | Improves power supply rejection.                                                                                                                                                                           |
| C3, C12   | 0.0033 $\mu$ F              | Forms integrator with internal gm block and op amp. Sets bandwidth conversion gain of 33 Hz/ $\mu$ A of gm current.                                                                                        |
| C4, C11   | 1 $\mu$ F                   | Output coupling capacitor. Output is at DC potential of $V_S/2$ .                                                                                                                                          |
| C5        | 0.1 $\mu$ F                 | Works with R1 and R2 to attenuate low frequency transients which could disturb control path operation.<br>$f_5 = \frac{1}{2\pi C5 (R1 + R2)} = 1.6 \text{ kHz}$                                            |
| C6        | 0.001 $\mu$ F               | Works with input resistance of pin 6 to form part of control path frequency weighting.<br>$f_6 = \frac{1}{2\pi C6 R_{PIN6}} = 5.3 \text{ kHz}$                                                             |
| C8        | 0.1 $\mu$ F                 | Combined with L8 and $C_L$ forms 19 kHz filter for FM pilot. This is only required in FM applications (Note 9).                                                                                            |
| L8, $C_L$ | 4.7 mH,<br>0.015 $\mu$ F    | Forms 19 kHz filter for FM pilot. L8 is Toko coil CAN-1A185HM (Notes 8, 9).                                                                                                                                |
| C9        | 0.047 $\mu$ F               | Works with input resistance of pin 9 to form part of control path frequency weighting.<br>$f_9 = \frac{1}{2\pi C9 R_{PIN9}} = 4.8 \text{ kHz}$                                                             |
| C10       | 1 $\mu$ F                   | Set attack and decay time of peak detector.                                                                                                                                                                |
| R1, R2    | 1 k $\Omega$                | Sensitivity resistors set the noise threshold. Reducing attenuation causes larger signals to be peak detected and larger bandwidth in main signal path. Total value of R1 + R2 should equal 1 k $\Omega$ . |
| R8        | 100 $\Omega$                | Forms RC roll-off with C8. This is only required in FM applications.                                                                                                                                       |

**Note 8:** Toko America Inc., 1250 Feehanville Drive, Mt. Prospect IL 60056

**Note 9:** When FM applications are not required, pin 8 and pin 9 hook-up as follows:



## Circuit Operation

The LM1894 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 gm block with a variable current, and an op amp configured as an integrator. As seen in *Figure 2*, 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 0.0033  $\mu$ F capacitor.

The purpose of the control paths 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 2*. The R1, R2 resistor divider adjusts the incoming noise level to open slightly the bandwidth of the low pass filter. Control path gain is about 60 dB 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  $\mu$ 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 gm blocks. The bandwidth sensitivity to gm current is 33 Hz/ $\mu$ A. In FM stereo applications at 19 kHz pilot filter is inserted between pin 8 and pin 9 as shown in *Figure 1*.

*Figure 3* is an interesting curve and deserves some discussion. Although the output of the DNR system is a linear function of input signal, the -3 dB bandwidth is not. This is due to the non-linear nature of the control path. The DNR system has a uniform frequency response, but looking at the -3 dB bandwidth on a steady state basis with a single frequency input can be misleading. It must be remembered that a single input frequency can only give a single -3 dB bandwidth and the roll-off from this point must be a smooth -6 dB/oct.

A more accurate evaluation of the frequency response can be seen in *Figure 4*. 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. White noise can mask pure tones. The total noise energy required to mask a pure tone must equal the energy of the tone itself. Within certain limits, the wider the band of mask-



## Application Hints

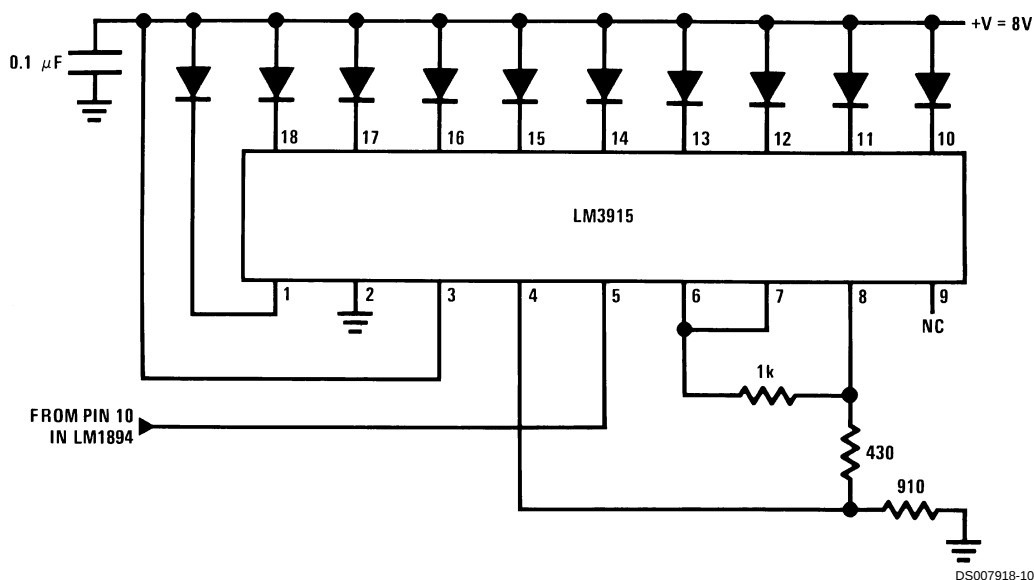
The DNR system should always be placed before tone and volume controls as shown in *Figure 1*. This is because any adjustment of these controls would alter the noise floor seen by the DNR control path. The sensitivity resistors R1 and R2 may need to be switched with the input selector, depending on the 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 open slightly 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 5*. 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 C12, can be scaled up or

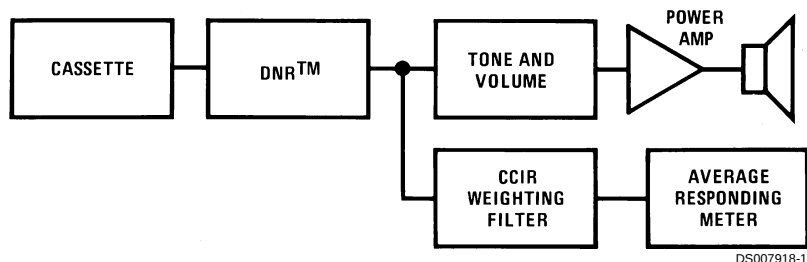
down. Since the bandwidth is inversely proportional to the capacitance, changing this 0.0039  $\mu\text{F}$  capacitor to 0.0033  $\mu\text{F}$  will change the typical bandwidth from 965 Hz–34 kHz to 1.1 kHz–40 kHz. With C3 and C12 set at 0.0033  $\mu\text{F}$ , the maximum bandwidth is typically 34 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 C10. Decay times can be decreased by paralleling a resistor with C10, and increased by increasing the value of C10.

When measuring the amount of noise reduction of the DNR 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 6*. 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.



**FIGURE 5. Bar Graph Display of Peak Detector Voltage**



**FIGURE 6. Technique for Measuring S/N Improvement of the DNR System**

## Application Hints (Continued)

### FOR FURTHER READING

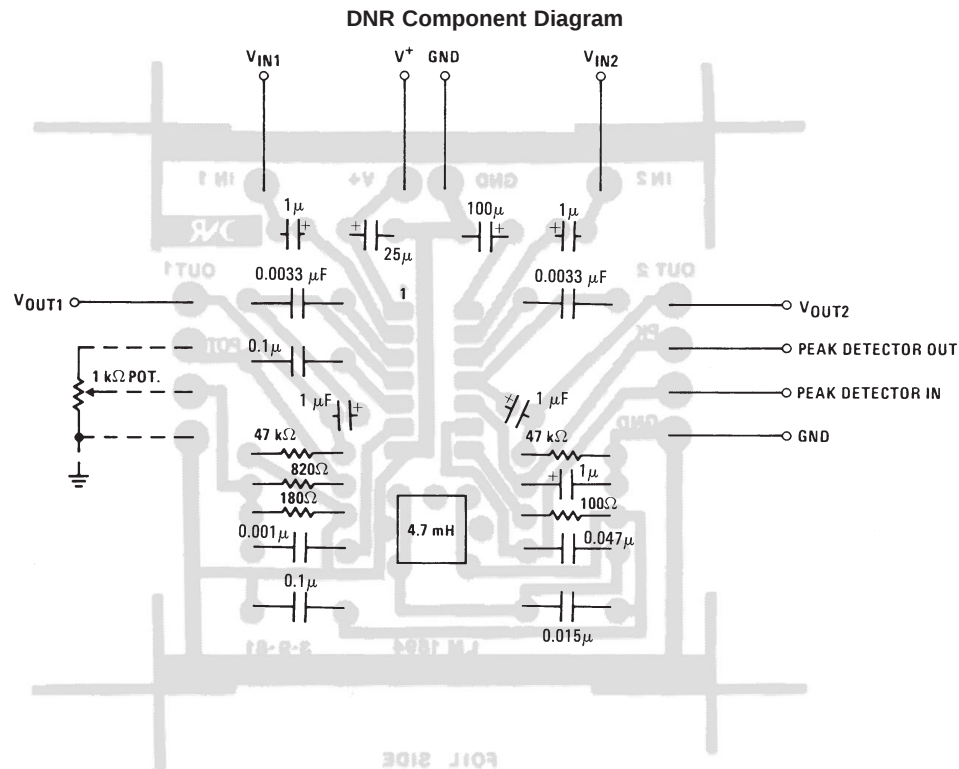
#### Tape Noise Levels

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.

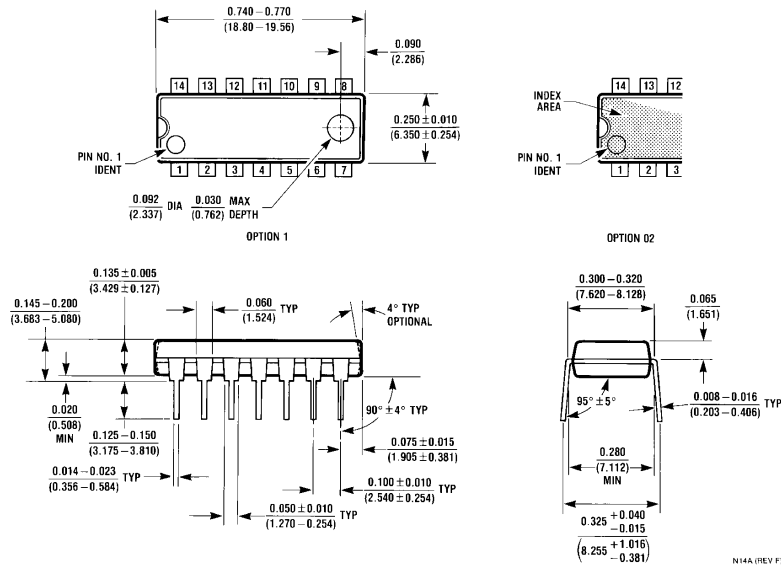
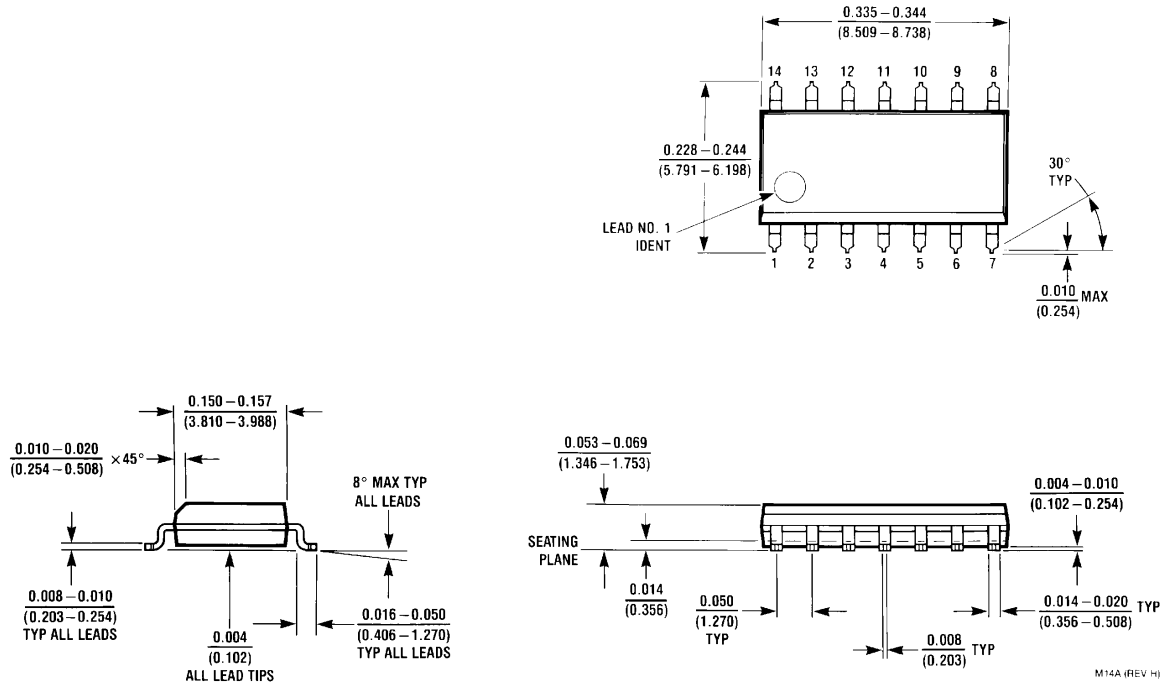
### Printed Circuit Layout

#### Noise Masking

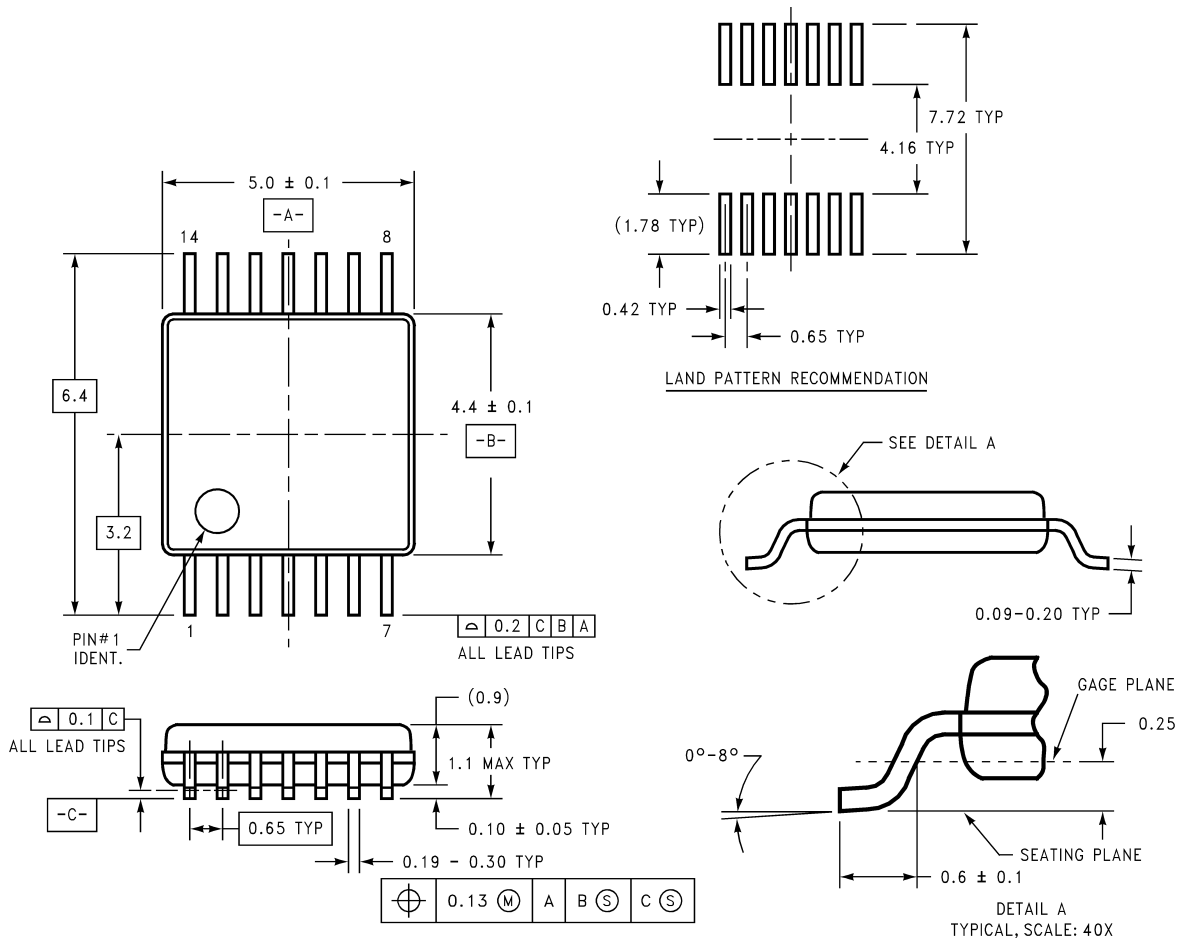
1. "Masking and Discrimination", Bos and De Boer, *JAES*, Volume 39, #4, 1966.
2. "The Masking of Pure Tones and Speech by White Noise", Hawkins and Stevens, *JAES*, Volume 22, #1, 1950.
3. "Sound System Engineering", Davis Howard W. Sams and Co.
4. "High Quality Sound Reproduction", Moir, Chapman Hall,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



# Physical Dimensions inches (millimeters) unless otherwise noted



# Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



DIMENSIONS ARE IN MILLIMETERS

MTC14 (REV C)

**TSSOP Package**  
**Order Number LM1894MT**  
**NS Package Number MTC14**

## LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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