



IECQ MFG.  
APPROVAL

## AM/FM RADIO SYSTEM

Providing all radio functions except VHF tuning, the ULN2204A AM/FM radio system excels in low-cost applications requiring a minimal parts count and high performance.

In the AM mode of operation, the device is a complete single-conversion superheterodyne broadcast or shortwave receiver with AGC and peak envelope detection. In the FM mode, the ULN2204A operates as a high-gain IF amplifier/limiter and phase-shift detector. A simple dc switch is used to change mode of operation.

A single external capacitor at pin 16 provides the AM-AGC time constant, the FM-AFC time constant, and RF decoupling. A single resistor at the same pin will adjust the AM gain for optimal system performance.

The audio amplifier will work into any speaker load of 8Ω or greater. Class-B operation of the audio power amplifier yields high efficiency at rated output with very-low quiescent power drain. The amplifier exhibits little crossover distortion. Its output impedance is significantly less than 1Ω.

The ULN2204A will work with a wide range of supply voltages, and is suitable for use in ac-powered table radios and in battery-powered (6 or 9 V) portable radios. This system will operate at supply voltages as low as 2 V at reduced volume without significant increase in distortion. Brown-outs or weak batteries need no longer be a major concern.

The ULN2204A is supplied in a 16-pin dual in-line plastic package with a copper lead frame that eliminates many decoupling problems and allows maximum power dissipation.

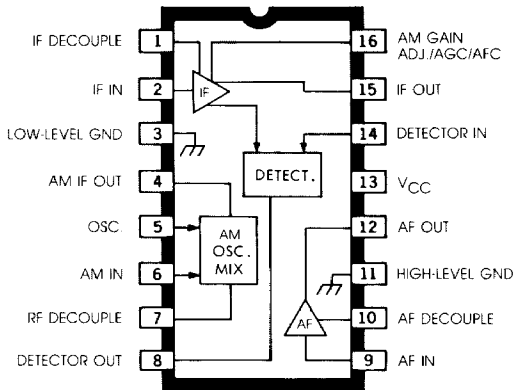
### FEATURES

- Low Harmonic Distortion
- Wide Operating Voltage Range
- Low Power Drain
- DC AM/FM Switching
- 30 μV Limiting Threshold
- Excellent AM Rejection
- Good Usable Sensitivity
- Pin-Compatible with HA12402, TA7613, TDA1083, U417B

### ABSOLUTE MAXIMUM RATINGS

AT T<sub>A</sub> = +25°C

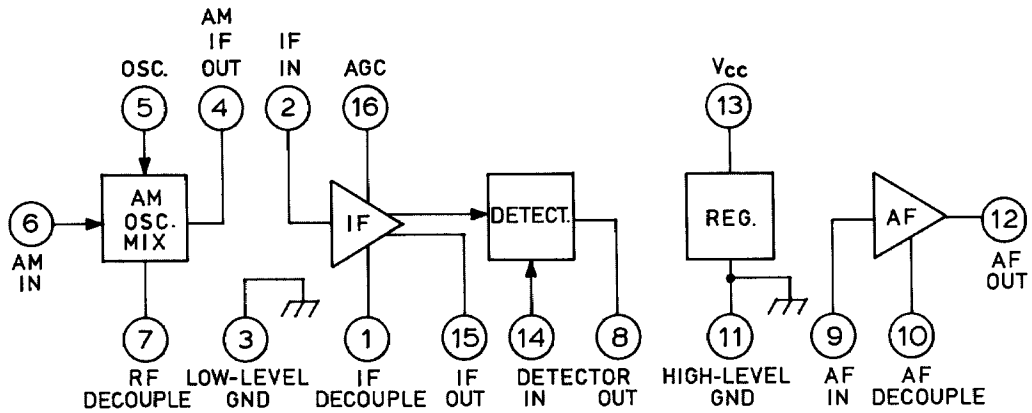
|  |                 |
|--|-----------------|
| Supply Voltage, V <sub>CC</sub> .....                | 12 V            |
| Package Power Dissipation, P <sub>D</sub> .....      | 1.0 W           |
| Operating Temperature Range,<br>T <sub>A</sub> ..... | -20°C to +85°C  |
| Storage Temperature Range,<br>T <sub>S</sub> .....   | -65°C to +150°C |



Dwg. PS-007

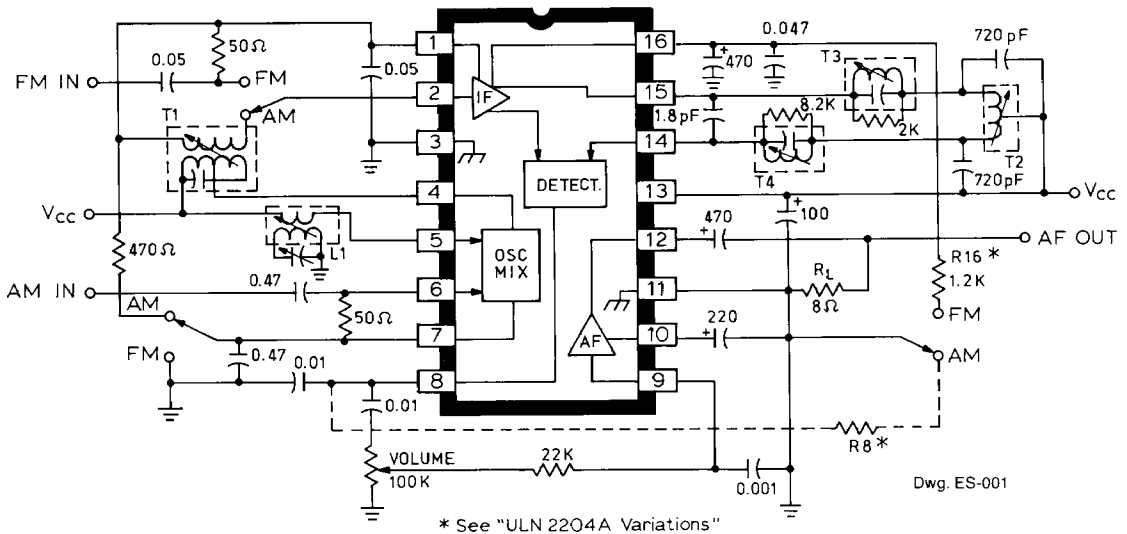
# ULN2204A AM/FM RADIO SYSTEM

## FUNCTIONAL BLOCK DIAGRAM



Dwg. FS-001

## TEST CIRCUIT

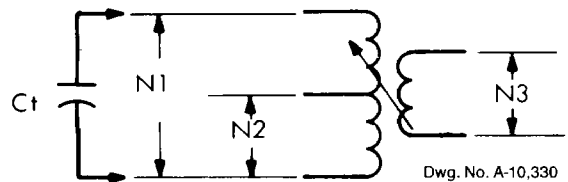


Dwg. ES-001

\* See "ULN 2204A Variations"

## COIL INFORMATION

|   |  |                               |
|---|--|-------------------------------|
| T <sub>1</sub> AM First IF<br>455 kHz                   | Q <sub>U</sub> = 120<br>N1:N2:N3 = 15:2.8:1<br>C <sub>i</sub> = 180 pF | Toko Part No.<br>RMC-2A7641A  |
| T <sub>2</sub> AM Second IF<br>455 kHz                  | Q <sub>U</sub> = 70<br>N1:N2 = 2:1<br>C <sub>i</sub> = 430 pF          | Toko Part No.<br>RLE-4A7642G0 |
| T <sub>3</sub> , T <sub>4</sub> FM Detector<br>10.7 MHz | Q <sub>U</sub> = 50<br>C <sub>i</sub> = 100 pF                         | Toko Part No.<br>BKAC-K3651HM |
| L <sub>1</sub> AM Oscillator<br>1455 kHz                | Q <sub>U</sub> = 50<br>N1:N3 = 9.8:1<br>C <sub>i</sub> = 39 pF         | Toko Part No.<br>RWO-6A7640BM |



# SPRAGUE

115 Northeast Cutoff, Box 15036  
Worcester, Massachusetts 01615-0036 (508) 853-5000  
Copyright © 1988 Sprague Electric Company, December 1988

# ULN2204A

## AM/FM RADIO SYSTEM

### ULN2204A-2A, -2B, -2C, -3A, -3B, and -3C

(Sprague Specification No. ULR8096)

### ELECTRICAL CHARACTERISTICS at $T_A = +25^\circ\text{C}$ , $V_{CC} = 6.0\text{ V}$

| Characteristic | Symbol | Test Conditions | Limits |      |      | Units |
|----------------|--------|-----------------|--------|------|------|-------|
|                |        |                 | Min.   | Typ. | Max. |       |

**FM MODE:**  $f_o = 10.7\text{ MHz}$ ,  $f_m = 400\text{ Hz}$ ,  $f_d = \pm 75\text{ kHz}$ , Peak Separation =  $550\text{ kHz}$ ,  $R_{16} = 1.2\text{ k}\Omega$

|                            |                |  |      |      |      |               |
|----------------------------|----------------|--|------|------|------|---------------|
| Input Limiting Threshold   | $V_{th}$       |  | –    | 30   | 60   | $\mu\text{V}$ |
| Detector Recovered Audio   | $V_o$          |  | 180  | 250  | 360  | mV            |
| Detector Output Distortion | $\text{THD}_D$ | $V_{in} = 10\text{ mVrms}$                                       | –    | 1.0  | 3.0  | %             |
| AM Rejection               | AMR            | $V_{in} = 10\text{ mVrms}$ , 30% AM,<br>$f_{AM} = 400\text{ Hz}$ | 35   | 50   | –    | dB            |
| Quiescent Terminal Voltage | $V_1$          |  | –    | 2.1  | –    | V             |
|                            | $V_8$          |  | –    | 1.7  | –    | V             |
|                            | $V_{16}$       | ULN2204A-2A, -2B and -2C only                                    | 2.55 | 2.75 | 3.05 | V             |
|                            |                | ULN2204A-3A, -3B, and -3C only                                   | 2.95 | 3.15 | 3.40 | V             |
| Quiescent Supply Current   | $I_{CC}$       | $V_{CC} = 6.0\text{ V}$  | –    | 10   | 20   | mA            |
|                            |                | $V_{CC} = 9.0\text{ V}$  | –    | 13   | 28   | mA            |

**AM MODE:**  $f_o = 1\text{ MHz}$ ,  $f_{ff} = 455\text{ kHz}$ ,  $f_m = 400\text{ Hz}$ , 30% AM,  $R_8 = \infty$  (ULN2204A-2A and -3A) or  $R_8 = 75\text{ k}\Omega$  (ULN2204A-2B and -3B) or  $R_8 = 36\text{ k}\Omega$  (ULN2204A-2C and -3C)

|                            |                |  |     |      |     |               |
|----------------------------|----------------|--|-----|------|-----|---------------|
| Sensitivity                |                | $V_{o(8)} = 20\text{ mVrms}$             | 1.6 | 4.0  | 8.0 | $\mu\text{V}$ |
| Detector Recovered Audio   | $V_o$          |  | 60  | 100  | 130 | mV            |
| Detector Output Distortion | $\text{THD}_D$ |  | –   | 1.0  | 3.0 | %             |
| Overload Distortion        |                | $P_{o(12)} = 100\text{ mW}$ , THD = 100% | 30  | 50   | –   | mV            |
| Usable Sensitivity         |                | 20 dB S + N/N                            | –   | 15   | 30  | $\mu\text{V}$ |
| Quiescent Terminal Voltage | $V_1$          |  | –   | 1.1  | –   | V             |
|                            | $V_8$          |  | –   | 1.6  | –   | V             |
|                            | $V_{16}$       |  | –   | 1.55 | –   | V             |
| Quiescent Supply Current   | $I_{CC}$       | $V_{CC} = 6.0\text{ V}$                  | –   | 10   | 14  | mA            |
|                            |                | $V_{CC} = 9.0\text{ V}$                  | –   | 13   | 21  | mA            |

**AUDIO AMPLIFIER:**  $f_o = 400\text{ Hz}$ ,  $R_L = 8\ \Omega$

|                            |          |                                   |     |     |     |    |
|----------------------------|----------|-----------------------------------|-----|-----|-----|----|
| Audio Gain                 | $A_e$    |                                   | 36  | 40  | 44  | dB |
| Output Power               | $P_o$    | $V_{CC} = 3.0\text{ V}$ , 10% THD | –   | 50  | –   | mW |
|                            |          | $V_{CC} = 6.0\text{ V}$ , 10% THD | 250 | 400 | –   | mW |
|                            |          | $V_{CC} = 9.0\text{ V}$ , 10% THD | 500 | 825 | –   | mW |
| Output Distortion          | THD      | $P_o = 100\text{ mW}$             | –   | 1.0 | 5.0 | %  |
| Quiescent Terminal Voltage | $V_{10}$ |                                   | –   | 1.1 | –   | V  |
|                            | $V_{12}$ |                                   | –   | 2.6 | –   | V  |

Typical values are given for circuit design information only.

# ULN2204A

## AM/FM RADIO SYSTEM

### ULN2204A-21, -22, -31, and -32

(Sprague Specification No. ULR4872)

### ELECTRICAL CHARACTERISTICS at $T_A = +25^\circ\text{C}$ , $V_{CC} = 6.0\text{ V}$

| Characteristic  | Symbol           | Test Conditions  | Limits |      |      | Units         |
|---|------------------|--|--------|------|------|---------------|
|   |                  |  | Min.   | Typ. | Max. |               |
| <b>FM MODE: <math>f_o = 10.7\text{ MHz}</math>, <math>f_m = 400\text{ Hz}</math>, <math>f_d = \pm 75\text{ kHz}</math>, Peak Separation = 550 kHz, <math>R_{16} = 1.2\text{ k}\Omega</math></b> |                  |  |        |      |      |               |
| Input Limiting Threshold  | $V_{th}$         |  | –      | 30   | 60   | $\mu\text{V}$ |
| Detector Recovered Audio  | $V_o$            |  | –      | 250  | –    | mV            |
| Detector Output Distortion  | THD <sub>D</sub> | $V_{in} = 10\text{ mVrms}$                                       | –      | 1.0  | –    | %             |
| AM Rejection  | AMR              | $V_{in} = 10\text{ mVrms}$ , 30% AM,<br>$f_{AM} = 400\text{ Hz}$ | 35     | 50   | –    | dB            |
| Quiescent Terminal Voltage  | $V_1$            |  | –      | 2.1  | –    | V             |
|   | $V_8$            |  | –      | 1.7  | –    | V             |
|   | $V_{16}$         | ULN2204A-21 and -22 only   | 2.55   | 2.75 | 3.05 | V             |
|   |                  | ULN2204A-31 and -32 only   | 2.95   | 3.15 | 3.40 | V             |
| Quiescent Supply Current  | $I_{CC}$         | $V_{CC} = 6.0\text{ V}$  | –      | 14   | 20   | mA            |
|   |                  | $V_{CC} = 9.0\text{ V}$  | –      | 18   | –    | mA            |

### AM MODE: $f_o = 1\text{ MHz}$ , $f_{if} = 455\text{ kHz}$ , $f_m = 400\text{ Hz}$ , 30% AM, $R_8 = \infty$

|                            |          |                              |      |     |      |               |
|----------------------------|----------|------------------------------|------|-----|------|---------------|
| Sensitivity                |          | $V_{o(8)} = 20\text{ mVrms}$ | –    | 5.0 | 10   | $\mu\text{V}$ |
| Detector Recovered Audio   | $V_o$    |                              | –    | 150 | –    | mV            |
| Overload Distortion        |          | 10% THD                      | –    | 10  | –    | mV            |
| Usable Sensitivity         |          | 20 dB S + N/N                | –    | 15  | 30   | $\mu\text{V}$ |
| Quiescent Terminal Voltage | $V_{16}$ | ULN2204A-21 and -31 only     | 1.40 | –   | 1.75 | V             |
|                            |          | ULN2204A-22 and -32 only     | 1.65 | –   | 2.00 | V             |
| Quiescent Supply Current   | $I_{CC}$ | $V_{CC} = 6.0\text{ V}$      | –    | 10  | –    | mA            |
|                            |          | $V_{CC} = 9.0\text{ V}$      | –    | 13  | –    | mA            |

### AUDIO AMPLIFIER: $f_o = 400\text{ Hz}$ , $R_L = 8\ \Omega$

|                            |          |                                   |     |     |     |    |
|----------------------------|----------|-----------------------------------|-----|-----|-----|----|
| Audio Gain                 | $A_e$    |                                   | 36  | 40  | 44  | dB |
| Output Power               | $P_o$    | $V_{CC} = 3.0\text{ V}$ , 10% THD | –   | 50  | –   | mW |
|                            |          | $V_{CC} = 6.0\text{ V}$ , 10% THD | 250 | 400 | –   | mW |
|                            |          | $V_{CC} = 9.0\text{ V}$ , 10% THD | 500 | 825 | –   | mW |
| Output Distortion          | THD      | $P_o = 100\text{ mW}$             | –   | 1.0 | 5.0 | %  |
| Quiescent Terminal Voltage | $V_{10}$ |                                   | –   | 1.1 | –   | V  |
|                            | $V_{12}$ |                                   | –   | 2.6 | –   | V  |

Typical values are given for circuit design information only.

# SPRAGUE

115 Northeast Cutoff, Box 15036  
Worcester, Massachusetts 01615-0036 (508) 853-5000

# ULN2204A AM/FM RADIO SYSTEM

## SMALL-SIGNAL AC CHARACTERISTICS

| Characteristic | Pin | Typical Value |
|----------------|-----|---------------|
|----------------|-----|---------------|

### FM Mode

|                      |   |               |
|----------------------|---|---------------|
| IF Input Impedance   | 2 | 40 k $\Omega$ |
| IF Input Capacitance | 2 | 4.0 pF        |

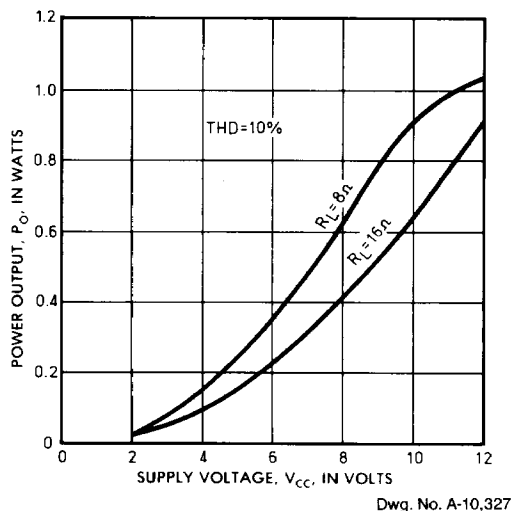
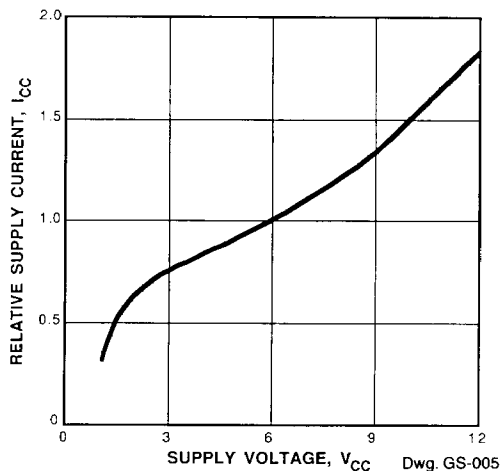
### AM Mode

|                          |   |                  |
|--------------------------|---|------------------|
| Mixer Input Impedance    | 6 | 4.5 k $\Omega$ * |
| Mixer Input Capacitance  | 6 | 5.5 pF           |
| Mixer Output Impedance   | 4 | 25 k $\Omega$    |
| Mixer Output Capacitance | 4 | 3.0 pF           |
| IF Input Impedance       | 2 | 100 k $\Omega$   |
| IF Input Capacitance     | 2 | 3.0 pF           |

### AUDIO AMPLIFIER

|                 |   |                |
|-----------------|---|----------------|
| Input Impedance | 9 | 250 k $\Omega$ |
|-----------------|---|----------------|

\*For optimum noise match, source impedance should be 2.5 k $\Omega$



## ULN2204A SELECTIONS FOR OPTIMAL SYSTEM PERFORMANCE

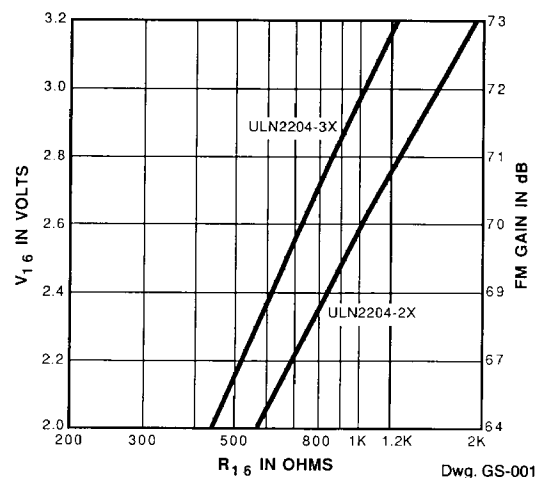
The performance of a receiver system using the ULN2204A can be kept within tighter performance limits by matching bias groupings, as identified by a device number suffix, and appropriate external resistors (R<sub>8</sub> and R<sub>16</sub>). With proper matching, consistent device performance can be obtained.

The first character of the suffix (the "3" in ULN2204A-31 or ULN2204A-3B) refers to FM gain and pin 16 output voltage as functions of the pin 16 load resistance (see graph).

In the FM mode, circuit stability is inversely related to gain or sensitivity and is affected by source and load, and printed wiring board layout. After an optimal FM-IF gain is determined for a particular circuit design, variations in that gain level can be minimized by matching the part-number suffix with the appropriate pin 16 load.

Some system designs derive the FM tuner supply, tuner bias, or AFC voltage from the pin 16 output. For example, if the tuner design requires 2.4 V at 2.9 mA (an equivalent R<sub>16</sub> of 820 $\Omega$ ), the graph indicates a ULN2204A-2x is required. A -3x device could be used by paralleling the equivalent 820 $\Omega$  tuner load with a fixed resistance for a 620 $\Omega$  total load. For AFC applications, note that as frequency increases V<sub>16</sub> voltage decreases. The amount of change is a factor of load impedance, detector coil characteristics, and device bias group.

In AM operation, stability is seldom a problem. However, large-signal overload can be optimized (to typically 30 mV) by matching the part-number suffix with an appropriate load resistor at pin 8. Additional loading may raise the overload point slightly, but AGC and sensitivity will be compromised. The AM grouping of a device, and recommended R<sub>8</sub> value in the application, is identified by the second character of the part number suffix (the '1' in ULN2204A-31 or the 'B' in ULN2204A-3B).



| Part Number Suffix | Recommended R <sub>8</sub> |
|--------------------|----------------------------|
| -2A or -3A         | $\infty$                   |
| -2B or -3B         | 75 k $\Omega$              |
| -2C or -3C         | 36 k $\Omega$              |
| -21 or -31         | $\infty$                   |
| -22 or -32         | 47 k $\Omega$              |

Continued next page...

# ULN2204A AM/FM RADIO SYSTEM

## Selections...(cont.)

Under the original Sprague Specification (No. ULR4872), the ULN2204A is sorted for dc voltage at pin 16 ( $R_8 = \infty$ ) as shown in the Electrical Characteristics. The newer Sprague Specification (No. ULR8096) is a more advanced selection technique that has been developed to match tighter AM-ac performance requirements with a specific pin 8 resistor. The ULN2204A-2A, -2B, -2C, -3A, -3B, and -3C are recommended for all new designs. The dc voltage at pin 16 is not characterized under this specification, but  $R_8$  must be set at the appropriate value in order to meet the specified ac limits.

Sprague Electric Company recommends that users not specify particular bias group selections except in unusual circumstances. All devices manufactured with Sprague part numbers are marked with appropriate part-number suffixes. Any single shipment to a customer will consist of devices from a single selection (single suffix).

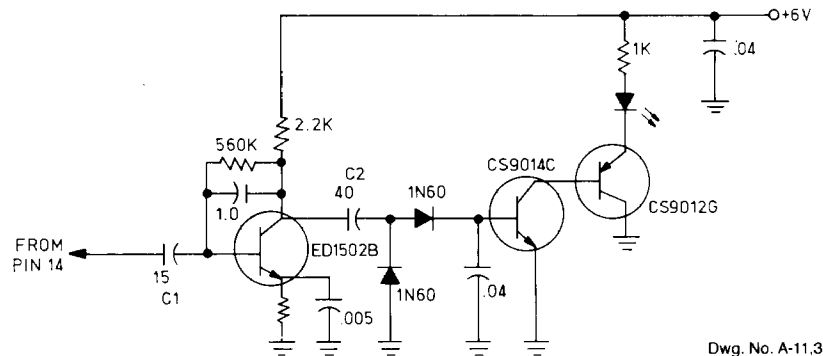
## TYPICAL APPLICATION

An AM/FM radio using the ULN2204A receiver system, designed for a usable FM sensitivity of about  $4 \mu\text{V}$  and an AM sensitivity of  $350 \mu\text{V}$ , is shown.

The two-stage FM tuner is operated at about 4 V. Reducing the pin 16 voltage to 1.8 V (by changing  $R_{16}$ ) reduces interstation noise and the FM-IF gain. An inductor at pin 12 ( $L_6$ ) prevents the wide-band audio amplifier from radiating RF noise in the AM spectrum.

A tuning indicator can be added to the radio circuit to provide an LED indication when the received signal strength exceeds  $7 \mu\text{V}$  in the FM mode or  $700 \mu\text{V/m}$  in the AM mode. The tuning indicator circuit reduces the IF gain by about 2 dB. The sensitivity may be adjusted by changing the value of  $C_1$  or  $C_2$ .

### TUNING INDICATOR



Dwg. No. A-11.355

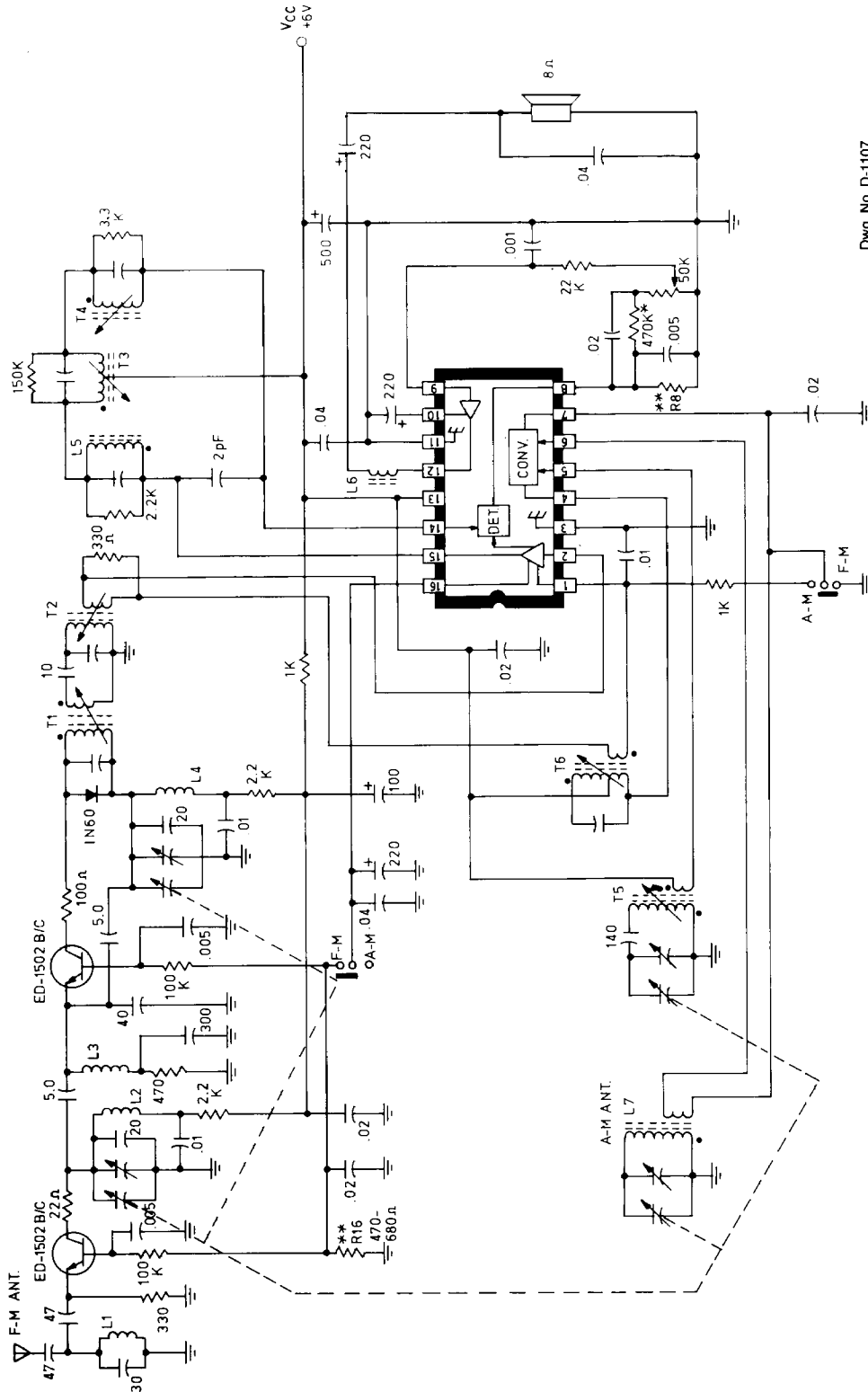
## COIL AND TRANSFORMER INFORMATION FOR TYPICAL APPLICATION

|    |             |  |
|----|-------------|--|
| L1 | FM Antenna  | 4½ turns, #20 AWG (0.8mm), 0.216" (5.5mm) dia.   |
| L2 | FM RF       | 3½ turns, #20 AWG (0.8mm), 0.177" (4.5mm) dia.   |
| L3 | FM IF Trap  | 16½ turns, #24 AWG (0.5mm), 0.177" (4.5mm) dia.  |
| L4 | FM Osc.     | 2½ turns, #20 AWG (0.8mm), 0.177" (4.5mm) dia.   |
| L5 | FM Detector | 15 $\mu\text{H}$ , $Q_u = 120$ @ 2.52 MHz  |
| L6 | Audio Choke | 10 $\mu\text{H}$ , $Q_u = 2$ @ 2.52 MHz;<br>3 turns through ferrite bead               |
| L7 | AM Antenna  | $Q_u = 250$ , 110:10 turns ratio;<br>Q2B core, 3.5" (90mm) $\times$ 0.394" (10mm) dia. |
| T1 | FM IF       | 82 pF, $Q_u = 90$ @ 10.7 MHz, 11:3 turns ratio   |
| T2 | FM IF       | 390 pF, $Q_u = 75$ @ 10.7 MHz, 5:2 turns ratio   |
| T3 | AM Detector | 390 pF, $Q_u = 130$ @ 455 kHz,<br>100 turns center-tapped                              |
| T4 | FM Detector | 150 pF, $Q_u = 90$ @ 10.7 MHz  |
| T5 | AM Osc.     | 460 $\mu\text{H}$ , $Q_u = 120$ @ 796 kHz, 10:1 turns ratio                            |
| T6 | AM IF       | 180 pF, $Q_u = 145$ @ 455 kHz, 15.5:1 turns ratio;<br>primary tapped at 82%            |

# 6 SPRAGUE

115 Northeast Cutoff, Box 15036  
Worcester, Massachusetts 01615-0036 (508) 853-5000

# ULN2204A AM/FM RADIO SYSTEM



Dwg. No. D-1107

## TYPICAL APPLICATION

\*Required only for VCC ≥ 9 V.  
 \*\*I F gain-dependent. See "ULN2204A Variations".

# ULN2204A AM/FM RADIO SYSTEM

## HOW TO ORDER

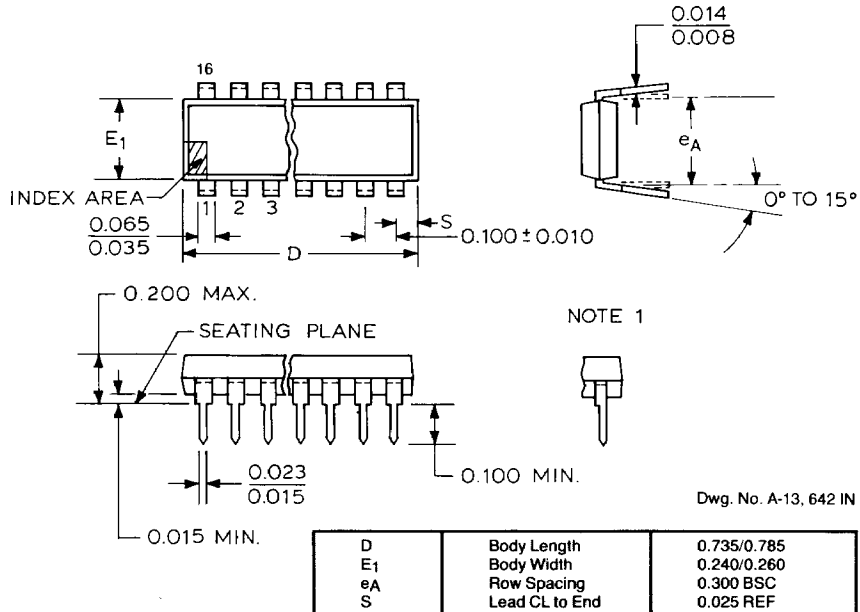
TO PLACE AN ORDER, obtain price and delivery information, request technical literature or applications assistance, contact your local Sprague Semiconductor sales office or sales representative, or:

From U.S. and Canada: **Sprague Electric Company Semiconductor Group**  
115 Northeast Cutoff  
Box 15036  
Worcester, MA 01615-0036  
Tel: (508) 853-5000  
Fax: (508) 853-5049  
Tlx: 203658, 221457

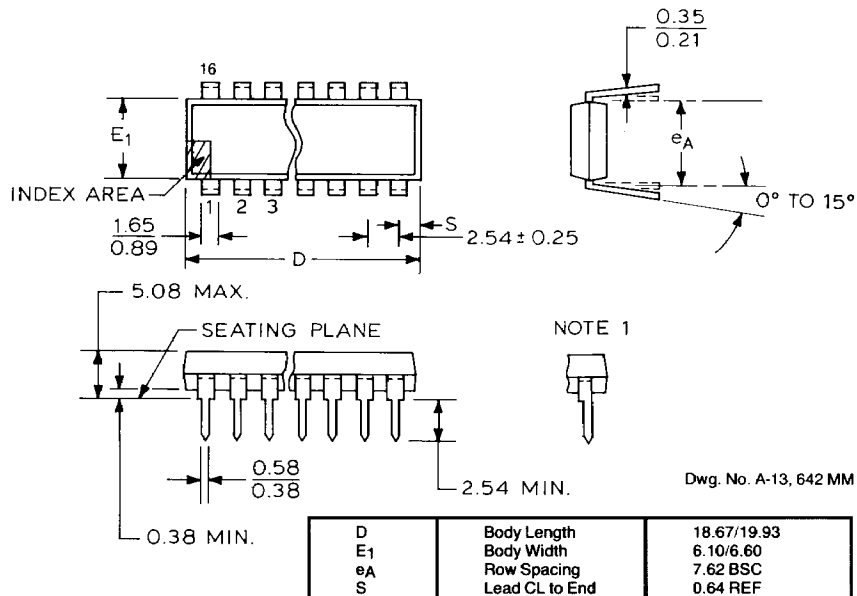
From Europe and Mideast: **Sprague Electric (U.K.) Ltd. Semiconductor Group**  
Balfour House  
Churchfield Road  
Walton on Thames  
Surrey KT12 2TD, UK  
Tel: (44-932) 253-355  
Fax: (44-932) 246-622  
Tlx: (851) 926618

From Asia: **Sprague Asia Ltd. Semiconductor Group**  
16th Floor, Lap Shun Centre  
552-556 Castle Peak Road  
Kwai Chung, N.T., HONG KONG  
G.P.O. Box 4289  
HONG KONG  
Tel: (852-0) 283188  
Fax: (852-0) 220042  
(852-0) 269603  
Tlx: (780) 43395

## DIMENSIONS IN INCHES



## DIMENSIONS IN MILLIMETERS (Based on 1" = 25.4 mm)



1. Leads 1, 8, 9, and 16 may be half-leads at vendor's option.

The Sprague Electric Company reserves the right to make, from time to time, such departures from the detail specifications as may be required to permit improvements in the design of its products. Components made under military approvals will be in accordance with the approval requirements.

The information included herein is believed to be accurate and reliable. However, the Sprague Electric Company assumes no responsibility for its use; nor for any infringements of patents or other rights of third parties which may result from its use.

- A. Dimensions shown as \_\_\_\_/\_\_\_\_ are Min./Max.
- B. Lead thickness is measured at seating plane or below.
- C. Lead spacing tolerance is non-cumulative.
- D. Exact body and lead configuration at vendor's option within limits shown.
- E. Lead gauge plane is 0.030" (0.762 mm) max. below seating plane.

# SPRAGUE

115 Northeast Cutoff, Box 15036  
Worcester, Massachusetts 01615-0036 (508) 853-5000

017805 ✓