



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.

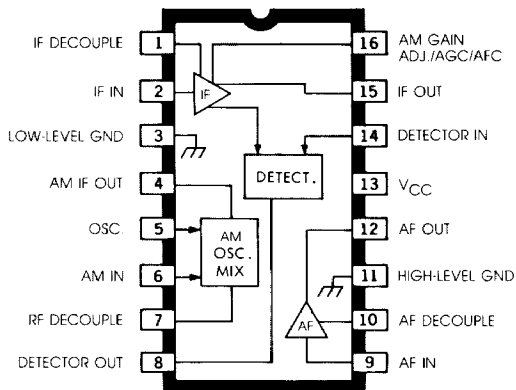
FEATURES

- 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_A = +25°C

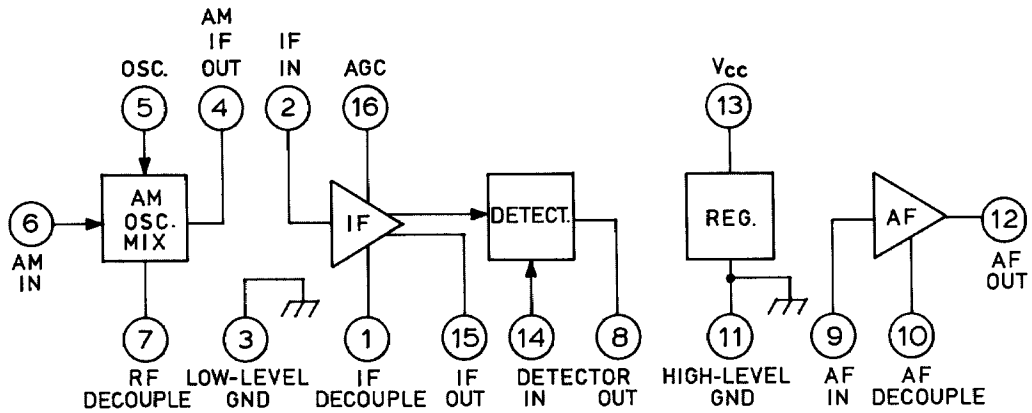
Supply Voltage, V _{CC}	12 V
Package Power Dissipation, P _D	1.0 W
Operating Temperature Range, T _A	-20°C to +85°C
Storage Temperature Range, T _S	-65°C to +150°C



Dwg. PS-007

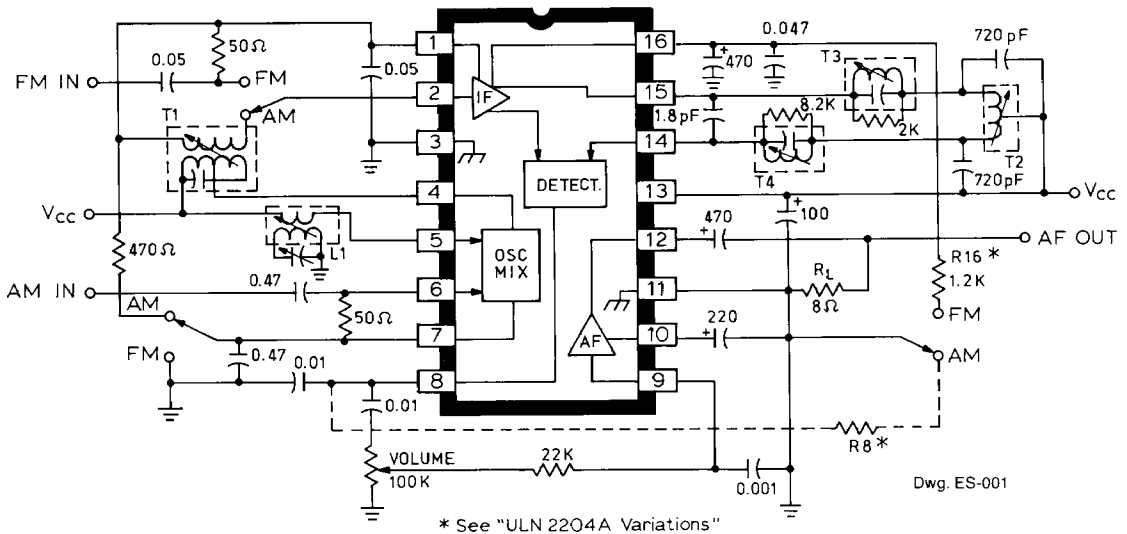
ULN2204A AM/FM RADIO SYSTEM

FUNCTIONAL BLOCK DIAGRAM



Dwg. FS-001

TEST CIRCUIT

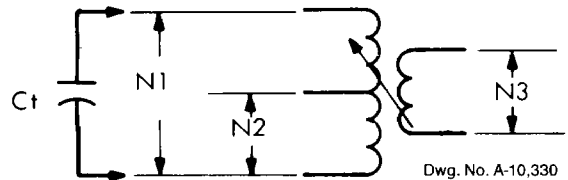


Dwg. ES-001

* See "ULN 2204A Variations"

COIL INFORMATION

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



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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 kHz, $R_{16} = 1.2\text{ k}\Omega$

Input Limiting Threshold	V_{th}		–	30	60	μV
Detector Recovered Audio	V_o		180	250	360	mV
Detector Output Distortion	THD_D	$V_{in} = 10\text{ mVrms}$	–	1.0	3.0	%
AM Rejection	AMR	$V_{in} = 10\text{ mVrms}$, 30% AM, $f_{AM} = 400\text{ Hz}$	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	μV
Detector Recovered Audio	V_o		60	100	130	mV
Detector Output Distortion	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	μV
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.	
FM MODE: $f_o = 10.7\text{ MHz}$, $f_m = 400\text{ Hz}$, $f_d = \pm 75\text{ kHz}$, Peak Separation = 550 kHz, $R_{16} = 1.2\text{ k}\Omega$						
Input Limiting Threshold	V_{th}		–	30	60	μV
Detector Recovered Audio	V_o		–	250	–	mV
Detector Output Distortion	THD _D	$V_{in} = 10\text{ mVrms}$	–	1.0	–	%
AM Rejection	AMR	$V_{in} = 10\text{ mVrms}$, 30% AM, $f_{AM} = 400\text{ Hz}$	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	μV
Detector Recovered Audio	V_o		–	150	–	mV
Overload Distortion		10% THD	–	10	–	mV
Usable Sensitivity		20 dB S + N/N	–	15	30	μV
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.

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ULN2204A AM/FM RADIO SYSTEM

SMALL-SIGNAL AC CHARACTERISTICS

Characteristic	Pin	Typical Value
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FM Mode

IF Input Impedance	2	40 k Ω
IF Input Capacitance	2	4.0 pF

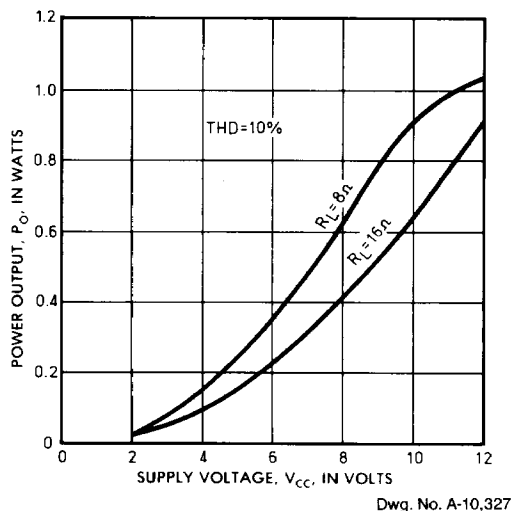
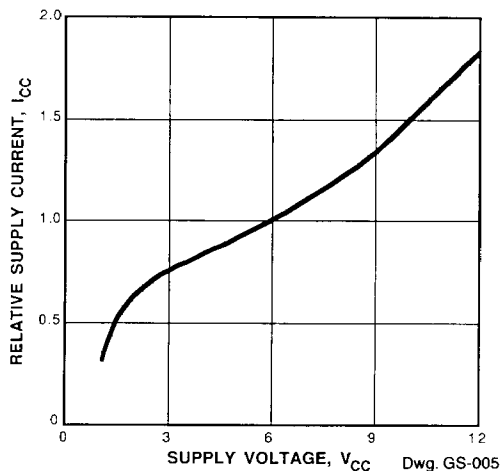
AM Mode

Mixer Input Impedance	6	4.5 k Ω *
Mixer Input Capacitance	6	5.5 pF
Mixer Output Impedance	4	25 k Ω
Mixer Output Capacitance	4	3.0 pF
IF Input Impedance	2	100 k Ω
IF Input Capacitance	2	3.0 pF

AUDIO AMPLIFIER

Input Impedance	9	250 k Ω
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*For optimum noise match, source impedance should be 2.5 k Ω



ULN2204A SELECTIONS FOR OPTIMAL SYSTEM PERFORMANCE

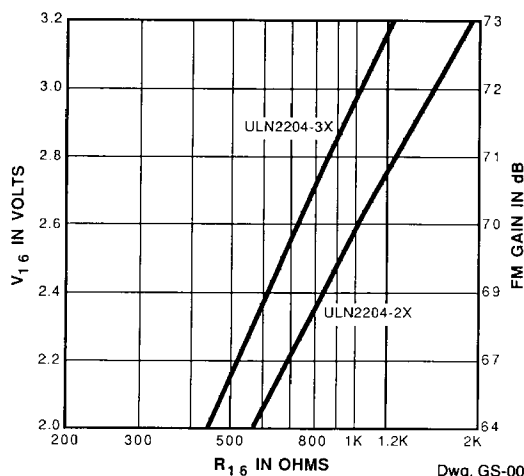
The performance of a receiver system using the ULN2204A can be kept within tighter performance limits by matching bias groupings, as identified by a device number suffix, and appropriate external resistors (R₈ and R₁₆). With proper matching, consistent device performance can be obtained.

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 R₁₆ of 820 Ω), the graph indicates a ULN2204A-2x is required. A -3x device could be used by paralleling the equivalent 820 Ω tuner load with a fixed resistance for a 620 Ω total load. For AFC applications, note that as frequency increases V₁₆ 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 R₈ 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 ₈
-2A or -3A	∞
-2B or -3B	75 k Ω
-2C or -3C	36 k Ω
-21 or -31	∞
-22 or -32	47 k Ω

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).

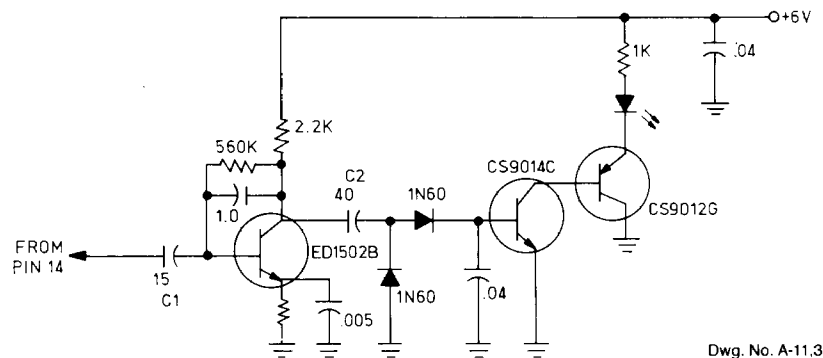
TYPICAL APPLICATION

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

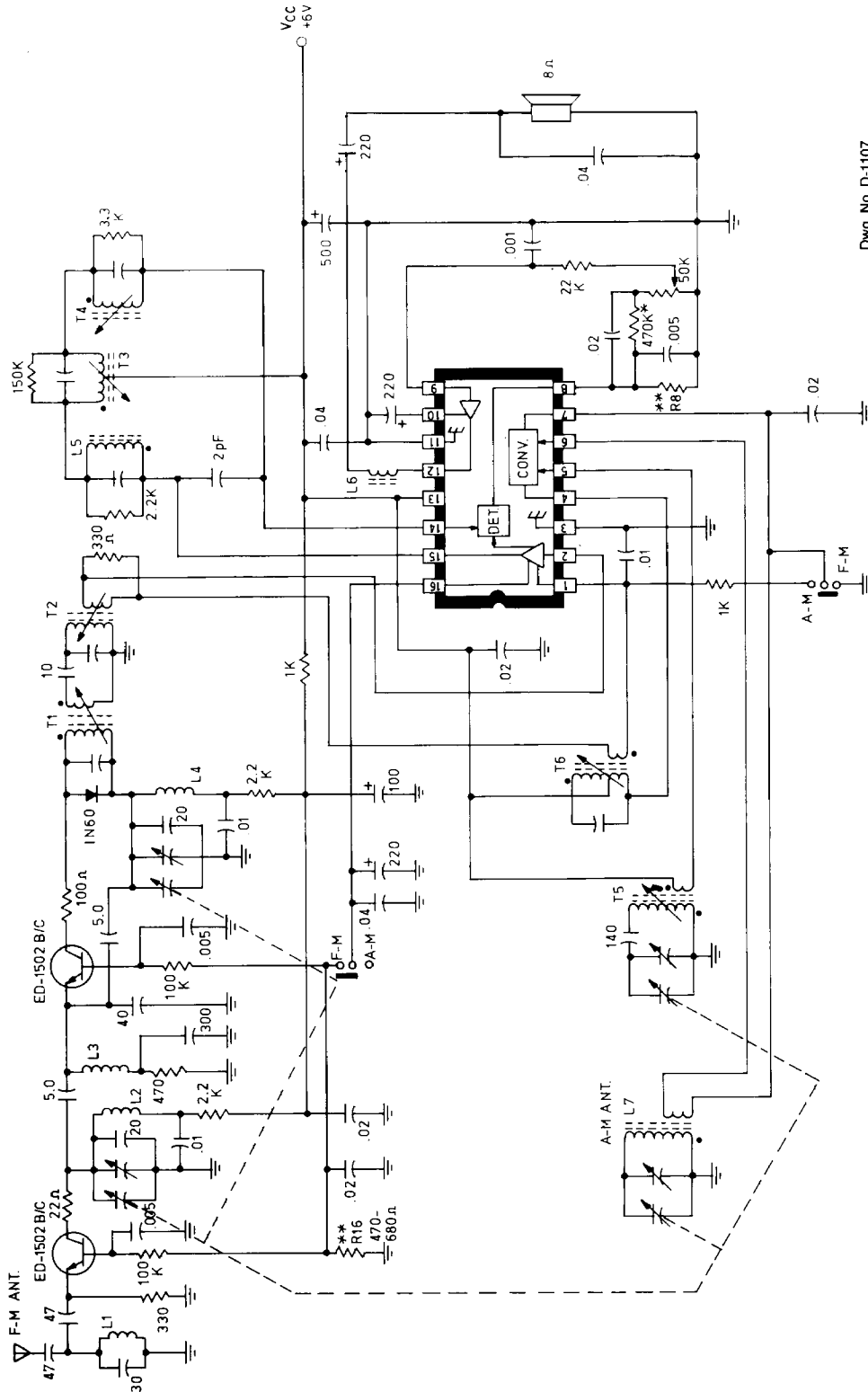
COIL AND TRANSFORMER INFORMATION FOR TYPICAL APPLICATION

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 μH , $Q_u = 120$ @ 2.52 MHz
L6	Audio Choke	10 μH , $Q_u = 2$ @ 2.52 MHz; 3 turns through ferrite bead
L7	AM Antenna	$Q_u = 250$, 110:10 turns ratio; 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, 100 turns center-tapped
T4	FM Detector	150 pF, $Q_u = 90$ @ 10.7 MHz
T5	AM Osc.	460 μH , $Q_u = 120$ @ 796 kHz, 10:1 turns ratio
T6	AM IF	180 pF, $Q_u = 145$ @ 455 kHz, 15.5:1 turns ratio; primary tapped at 82%

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ULN2204A AM/FM RADIO SYSTEM



Dwg. No. D-1107

TYPICAL APPLICATION

*Required only for $V_{CC} \geq 9V$.
 **I F gain-dependent. See "ULN2204A Variations".

ULN2204A AM/FM RADIO SYSTEM

HOW TO ORDER

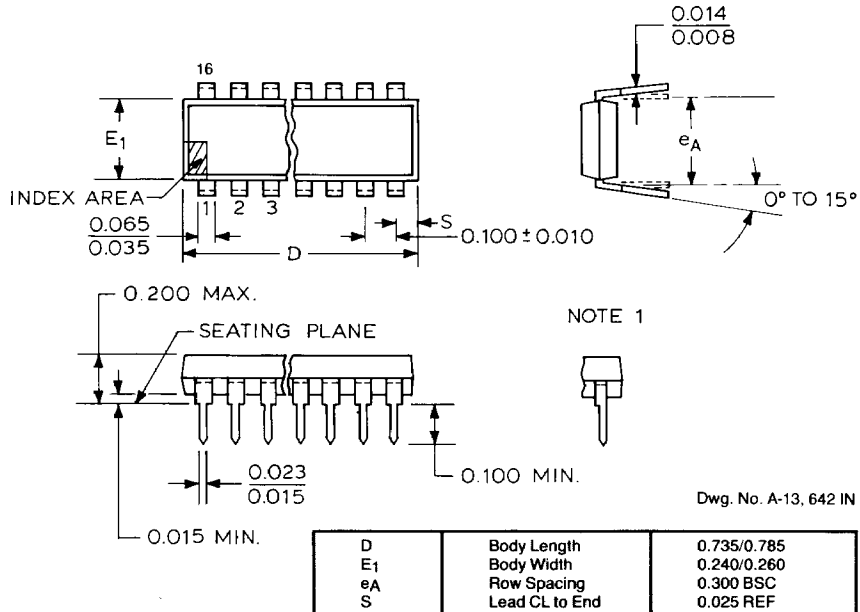
TO PLACE AN ORDER, obtain price and delivery information, request technical literature or applications assistance, contact your local Sprague Semiconductor sales office or sales representative, or:

From U.S. and Canada: **Sprague Electric Company Semiconductor Group**
115 Northeast Cutoff
Box 15036
Worcester, MA 01615-0036
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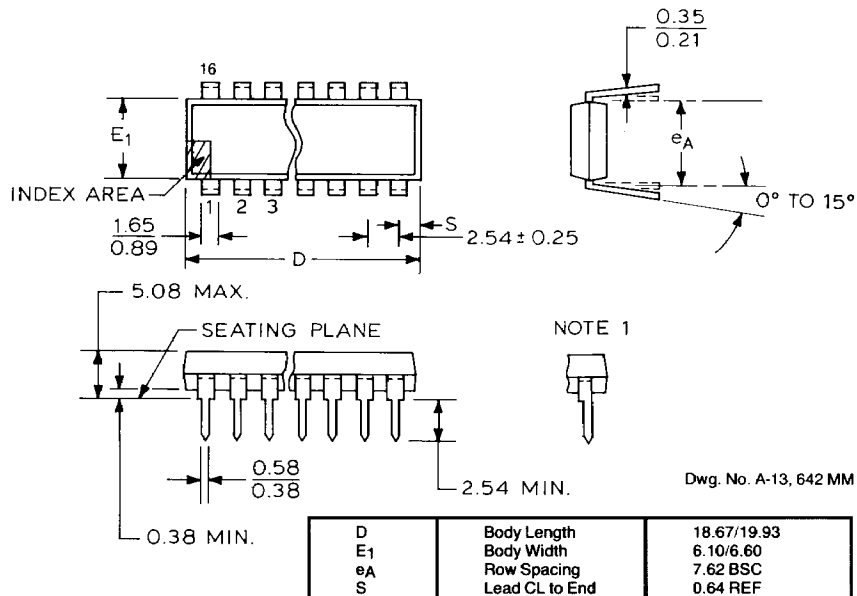
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(852-0) 269603
Tlx: (780) 43395

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.

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