National Semiconductor

LM1866 Low Voltage AM/FM Receiver

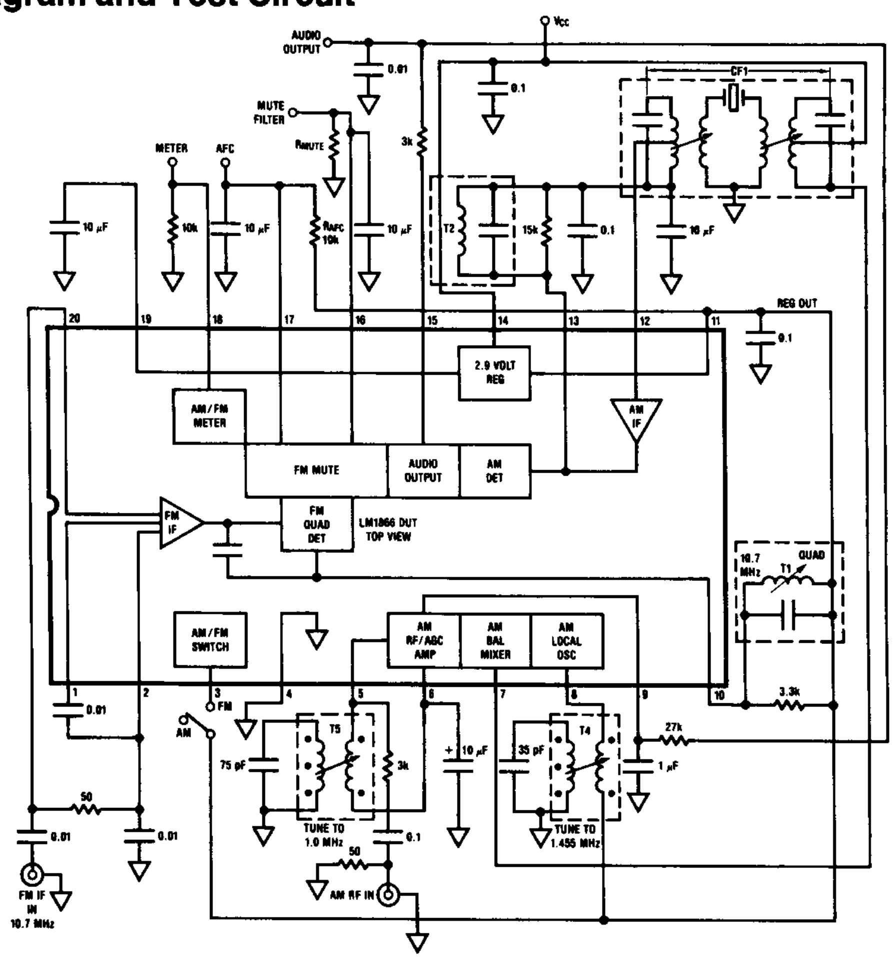
General Description

The LM1866 has been designed for high quality battery powered medium wave AM and FM receiver applications requiring operation down to 3V. The AM section contains a fully balanced, wide dynamic range, gain controlled mixer stage buffered from a single pin local oscillator. A two pin compound IF amplifier and internal detector provide a low distortion high level audio output. An AM/FM signal strength meter voltage is provided to a single output pin. The FM section contains a six stage limiting IF amplifier, quadrature detector, AFC output, deviation audio muting and noise operated audio muting. While designed for the high ripple, high battery impedance conditions found at the end of life for four "C" or "D" cells, the LM1866 will operate equally well at supply voltages up to 15V.

Features

- Operation from 3V to 5V
- Excellent power supply ripple rejection
- Fully balanced, wide dynamic range, AM mixer stage
- Internal AM detector for minimum tweet interference
- Single pole DC AM/FM mode switching
- Six stage FM IF limiting amplifier for excellent AM rejection
- "Soft" FM deviation and noise operated audio muting
- FM quadrature detector
- Single pin AM/FM meter output
- Single pin matched level AM/FM audio output

Block Diagram and Test Circuit



TL/H/7908–1

Order Number LM1866N
See NS Package Number N20A

Coil Data:
T2, Toko 159GC-A3785
CF1, Toko CFU-90D

T1, Toko KAC K2318HM
T4 = T5, Toko RBO6A5105

Toko America
1250 Feehanville Drive
Mount Prospect, IL 60056
(312) 297-0070

Absolute Maximum Ratings

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

Supply Voltage (Pin 14)	15V
Package Dissipation (Note 1)	1900 mW
Storage Temperature Range	−55°C to +150°C
Operating Temperature Range	0°C to +70°C
Lead Temperature (Soldering, 10 sec.)	260°C

Electrical Characteristics (Test Circuit, T_A = 25°C)

Parameter	Conditions	Min	Typ	Max	Units
STATIC DC CHARACTERISTICS: e_{IN} = 0, R_{MUTE} = 0Ω, V_{CC} = 6V					
Operating Supply Range, V14		3	6	15	V
Supply Current, I_{14}	AM Mode		15	27	mA
Supply Current, I_{14}	FM Mode		16	24	mA
Regulator Output Voltage, V11			2.9		V
Meter Output Voltage, V18	AM Mode		0	0.2	V
Meter Output Voltage, V18	FM Mode		0	0.2	V
AFC Output Voltage, V17	FM Mode		2.9		V
AM/FM Audio Output Resistance, R_o15			3		kΩ
AM DYNAMIC CHARACTERISTICS: f_{AM} = 1 MHz, f_{MOD} = 1 kHz, m = 0.3, V_{CC} = 6V					
Maximum Sensitivity	e_{AM} for e_o = 6 mV		9		μV
20 dB Quieting Sensitivity	e_{AM} for e_o = 20 dB S/N		25		μV
Signal to Noise Ratio	e_{AM} = 10 mV	40	50		dB
Total Harmonic Distortion	e_{AM} = 10 mV		0.3		%
Total Harmonic Distortion	e_{AM} = 10 mV, m = 0.8		1	2	%
Audio Output Level	e_{AM} = 10 mV	70	120		mV
Overload Distortion	e_{AM} = 50 mV, m = 0.8		2	12	%
Meter Output Voltage	e_{AM} = 1 mV		2.0	3.0	V
Meter Output Voltage	e_{AM} = 50 mV		3.0	3.5	V
FM DYNAMIC CHARACTERISTICS: f_{FM} = 10.7 MHz, f_{MOD} = 400 Hz, Δf = ±75 kHz, V_{CC} = 6V					
−3 dB Limiting Sensitivity	e_{FM} for −3 dB Limiting Sensitivity		20	35	μV
Signal to Noise Ratio	e_{FM} = 10 mV	60	76		dB
AM Rejection	e_{FM} = 10 mV, 30% AM Mod	40	55		dB
Total Harmonic Distortion	e_{FM} = 10 mV		0.5	1	%
Audio Output Level	e_{FM} = 10 mV, 30% FM Mod	60	120		mV
Meter Output Level	e_{FM} = 1 mV		1.3	2.3	V
Meter Output Level	e_{FM} = 50 mV		2.0	2.8	V
± Deviation Mute (Notes 2, 4)	e_{FM} = 10 mV, R_{AFC} = 10k		40		kHz
R_{MUTE} for Noise Mute (Notes 3, 4)	Set e_{FM} for −3 dB Limiting Sensitivity	2	5	10	kΩ
Max Audio Mute Attenuation		60	75		dB

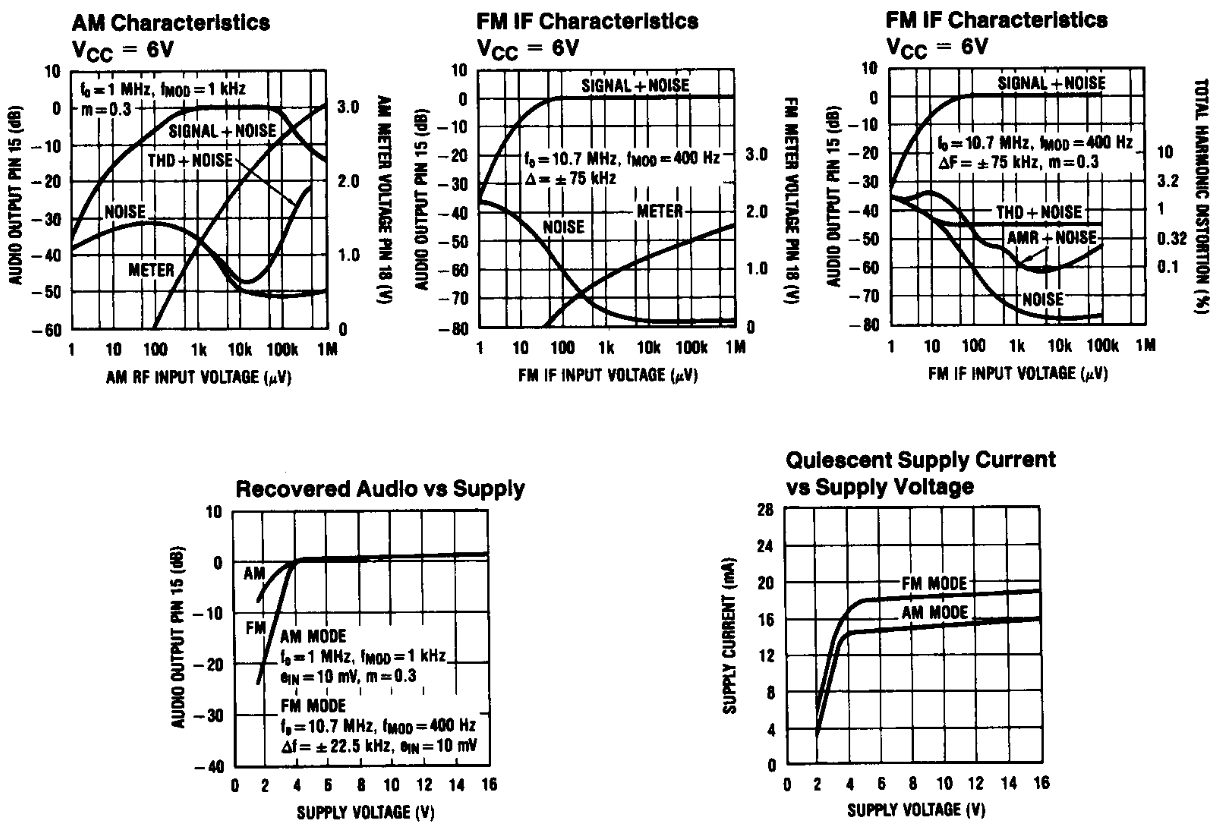
Note 1: Above T_A = 25°C, derate based on $T_{J(max)}$ = 150°C and θ_{JA} = 65°C/W.

Note 2: R_{MUTE} = 2 kΩ, e_{FM} = 10 mV, adjust center frequency for V_{AFC} = V_{REG}, record f_{FM}, adjust ± f_{FM} for >50 dB audio mute attenuation.

Note 3: Adjust R_{MUTE} from 2k to 10k for >50 dB audio mute attenuation. Set e_{FM} = 10 mV and check for mute off.

Note 4: When R_{MUTE} = 0Ω, the deviation and noise operated mute functions are disabled. When R_{MUTE} = 2 kΩ, only the noise mute function is disabled. The deviation mute bandwidth is set by the R_{AFC} resistor. The noise mute threshold is set by the R_{MUTE} resistor. Test circuit noise bandwidth characteristics prevent noise mute operation for IF input levels below the −3 dB limiting threshold. When the FM IF is used with a tuner, full noise mute capability is accessible (See Applications Information).

Typical Performance Characteristics (Test Circuit)



TL/H/7908-2

Applications Information

(See Typical Applications and LM1866 Schematic Diagram)

VOLTAGE REGULATOR SECTION

Because of the wide supply voltage range and high ripple conditions expected in battery or low cost transformer supplies, the LM1866 uses a band gap referenced active voltage regulator which is externally compensated at pin 19. This capacitor, when made large enough, improves the supply rejection and decreases the noise bandwidth to a level well below the AM reception frequencies. A 0.1 μF capacitor will compensate the regulator for low noise operation while 50 μF (max) will improve supply rejection and the maximum FM audio mute attenuation characteristics. During power turn on, the pin 19 capacitor is quick-charged to its normal operating voltage so that the AM or FM sections are in operation before the audio amplifier turn on delay has timed out. See LM1895/LM2895 and LM1896/LM2896 data sheets for additional audio amplifier information.

AM SECTION

The AM section contains a fully balanced mixer stage with the RF input applied to a differential, diode degenerated, transistor pair at pins 5 and 6. DC feedback is provided by the loopstick secondary winding. The mixer output 1st IF transformer at pin 7 should be returned to V_{CC} at pin 14 to allow maximum undistorted output swing when tuning between stations. RF and AGC decoupling at pin 6 removes noise and lowers audio distortion.

The mixer upper pairs are switched differentially by a buffer amplifier from the pin 8 local oscillator. DC feedback is provided by the oscillator coil secondary winding to the pin 11 regulator voltage.

The oscillator frequency is given by:

$$f_O = \frac{0.159}{\sqrt{LC}},$$

and the peak swing is given by: $V_P = IZ$ ($I = 700\ \mu A$, Z = tank impedance at resonance). V_P should be between 0.3V and 0.5V to maintain an undistorted output at low supplies.

The two stage AM IF amplifier at pins 12 and 13 requires output to input DC feedback and external decoupling. The IF gain is given by:

$$A_V = \frac{Z_L}{12}$$

Applications Information (Continued)

where Z_L equals resonant unloaded tank impedance in parallel with R_{EXT}. In most applications Z_L = 10k and

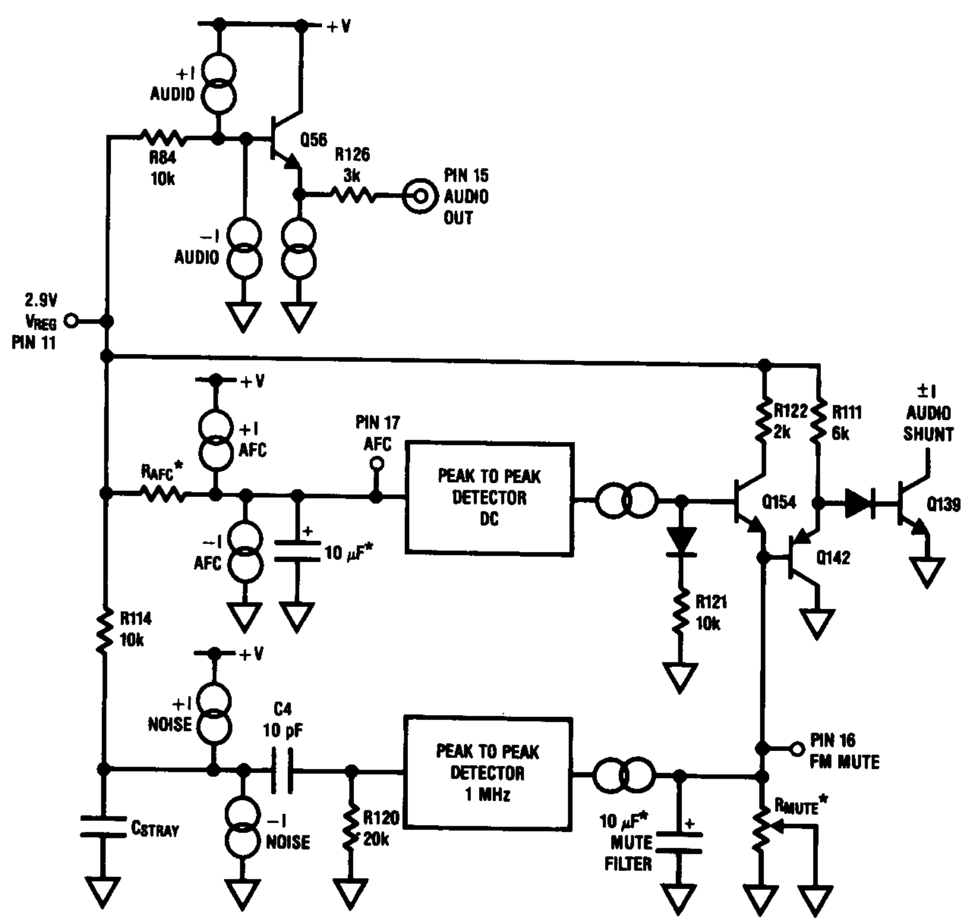
$$Q_L = \frac{Z_L}{X_C} = 5$$

where R_{EXT} = an external IF gain setting resistor and X_C = impedance of tank tuning capacitor. A rule of thumb for setting the IF gain would be to adjust R_{EXT} for 20 dB audio S/N when the audio has dropped 10 dB below the level found at the AGC threshold. (Because of the low Q_L, a non-tuned coil is acceptable.)

The output of the IF amplifier drives an internal detector which is operating at low currents. This results in very low 2nd and 3rd IF harmonic radiation for minimal tweet interference.

FM SECTION

The FM section contains a six stage limiting amplifier, quadrature detector, AFC output, deviation mute detector and a high frequency noise mute detector. (See *Figure 1* for the Simplified Mute Circuit Schematic.) The output of the quadrature detector is split into three current source pairs. The ± audio current and internal load resistor R84 provide the audio output voltage via Q56 to pin 15. The ± AFC current, external load resistor (R_{AFC}) and the 10 µF capacitor provide an audio decoupled AFC voltage to pin 17. The ± noise current and internal load resistor R114 provide a wideband detector output that is limited in frequency by C_{STRAY}. With the addition of internal C4 and R120 a band pass filter (f_o ≅ 1 MHz) is realized at the input of the peak to peak detector. The output current, flowing in resistor R_{MUTE} and filtered by a capacitor, provides a mute voltage at pin 16. When the mute voltage rises to approximately one V_{BE}, transistor Q139 will start to shunt the ± audio current away from R84, muting the audio output. The value of the R_{MUTE} resistor will determine the minimum audio signal to noise ratio at which one wishes to mute. The deviation mute detector will output a current only when the AFC voltage is offset above or below the V_{REG} voltage. Load resistor R121 and transistor Q154 will convert this current to a mute voltage at pin 16. This is done to prevent interaction between the two detector output currents. The external R_{AFC} resistor is used to set the deviation mute bandwidth so that the pin 16 mute voltage is one V_{BE} at the desired frequency band edge. When disabling the mute functions, pin 16 is shorted to ground, preventing Q139 from becoming active.



TL/H/7908-3

*External component

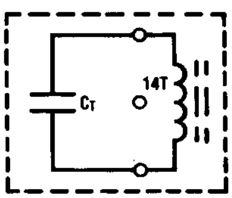
FIGURE 1. Simplified Mute Circuit Schematic

Applications Information (Continued)

TABLE I. Typical Application External Coil and Component Selection Guide

Component	Typical Value	Purpose
C1A, B, C, D	—	AM/FM tuning capacitor
R1, C2, C3	330Ω, 0.01 μF	FM IF decoupling, filter match and DC feedback
C4	1 μF–10 μF	AM/RF/AGC decoupling
R5, C5	27k, 1 μF	Sets AM AGC time constant
R6	120k–150k	Optional: decreases AM audio output but improves AM meter threshold
C6	0.1 μF	Regulator output decoupling
C7, C8	0.1 μF, 10 μF	AM IF/audio decoupling
R4 (R_{EXT})	15k	Sets AM IF gain
R7, C15, C14	10Ω, 0.1 μF, 100 μF	Supply decoupling
R3, C10	3k, 0.01 μF	Sets FM de-emphasis/AM smoothing Audio post filter pole is given by: $f = \frac{0.159}{R_T C10'}$ when $R_T = R3 + R_o15 = R3 + 3\ k\Omega$
R_{MUTE}, C11	0 to 10k, 10 μF	Sets noise mute threshold, filter. 0Ω will turn off mute function.
R_{AFC}, C12	10k, 10 μF	Sets deviation mute bandwidth, audio decoupling
C13	10 μF	Regulator decoupling and supply rejection filter

T1



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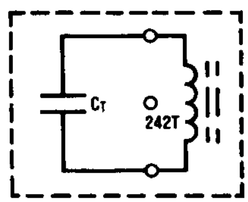
C_T = 82 pF
Qu ≥ 70
f = 10.7 MHz
Part no. KAC K2318HM Toko

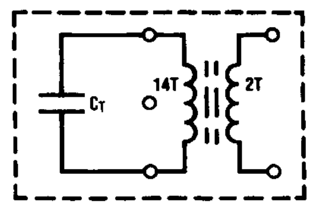
T2



TL/H/7908–5

C_T = 180 pF
Qu = 14
f = 455 kHz
Part no. 159GC-A3785 Toko

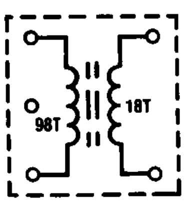
T3



TL/H/7908–6

C_T = 50 pF
Qu = 80
f = 10.7 MHz
Part no. NS-107C
Apollo Electronics Corp.

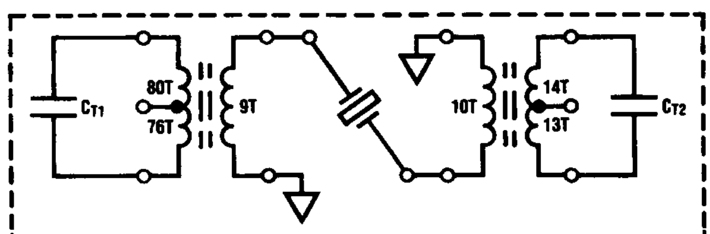
T4 and T5 MW Oscillator Coil



TL/H/7908–7

L = 360 μH
f = 796 kHz
Qu = 160
Tuning freq. = 985 kHz–2105 kHz
Part no. RBO6A5105 Toko

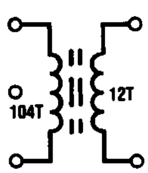
CF1



TL/H/7908–8

Toko CFU-090D or equivalent
f = 455 kHz, BW > 4.8 kHz

MW Antenna Coil

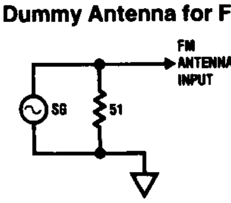


TL/H/7908–9

L = 650 μH
f = 796 kHz
Qu = 200
Tuning freq. = 530 kHz–1650 kHz

L7 SWG #20, N = 3 1/2T, ID = 5 mm
L5 SWG #20, N = 3 1/2T, ID = 5 mm
L6 L = 0.44 μH, N = 4 1/2T, Qu = 70

Dummy Antenna for FM



TL/H/7908–10

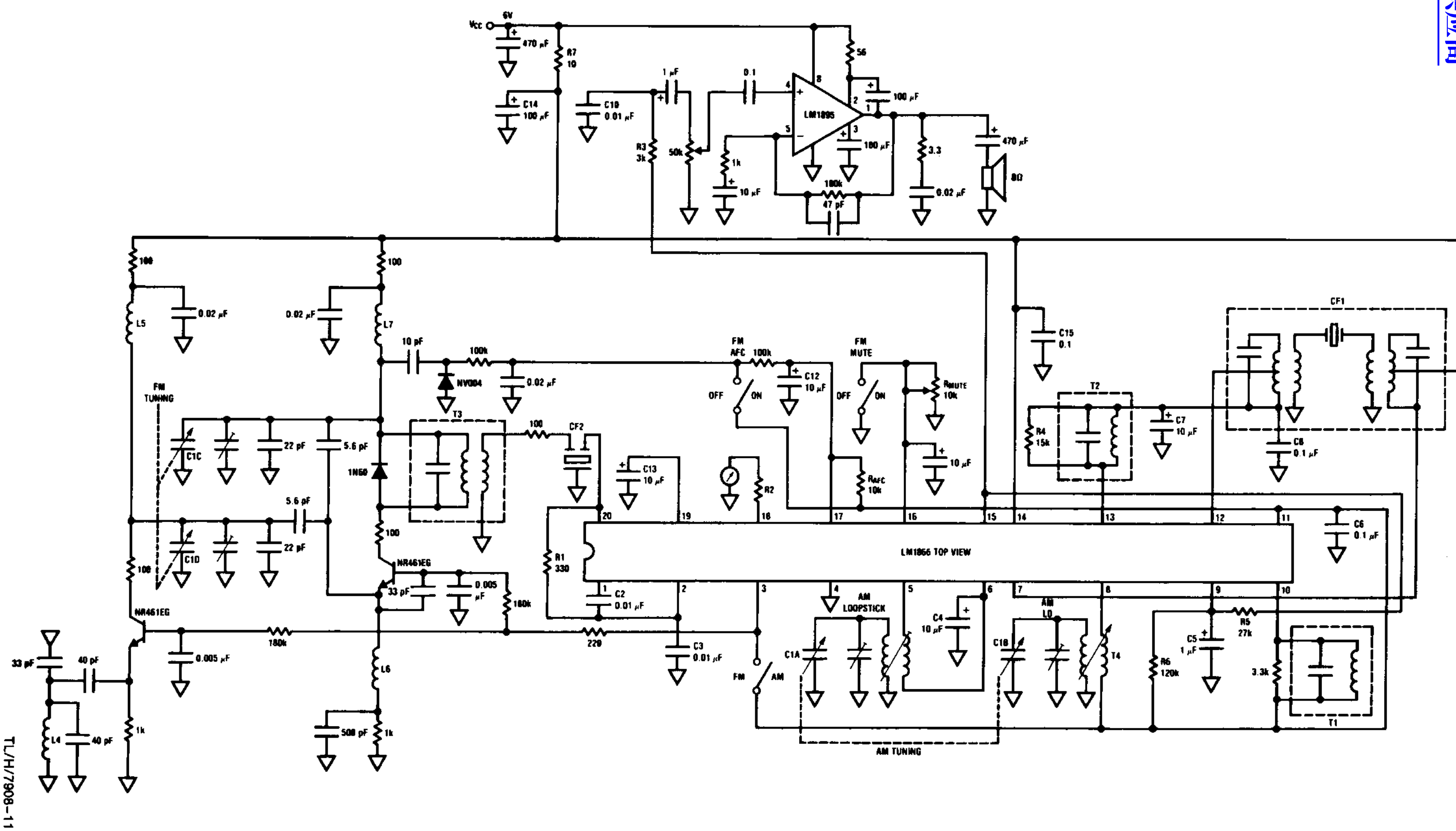
Variable Tuning Capacitor
Type: QT-22124 Toko
Capacitance: AM C1A 4 pF–142 pF, C1B 4–60 pF
FM 2.5 pF–20 pF C1C, C1D

AM Performance (525 kHz–1650 kHz)
- Maximum sensitivity: 100 μV/m
- 20 dB quieting sensitivity: 250 μV/m
- Tweet* worst case: 5%
  100 mV/m: 1.5%

FM Performance (88 MHz–108 MHz)
- 30 dB quieting sensitivity: 3.5 μV
- −3 dB limiting sensitivity: 7 μV

See Table I for coil and numbered component data.

See LM1895/LM2895 data sheet for audio amp info.

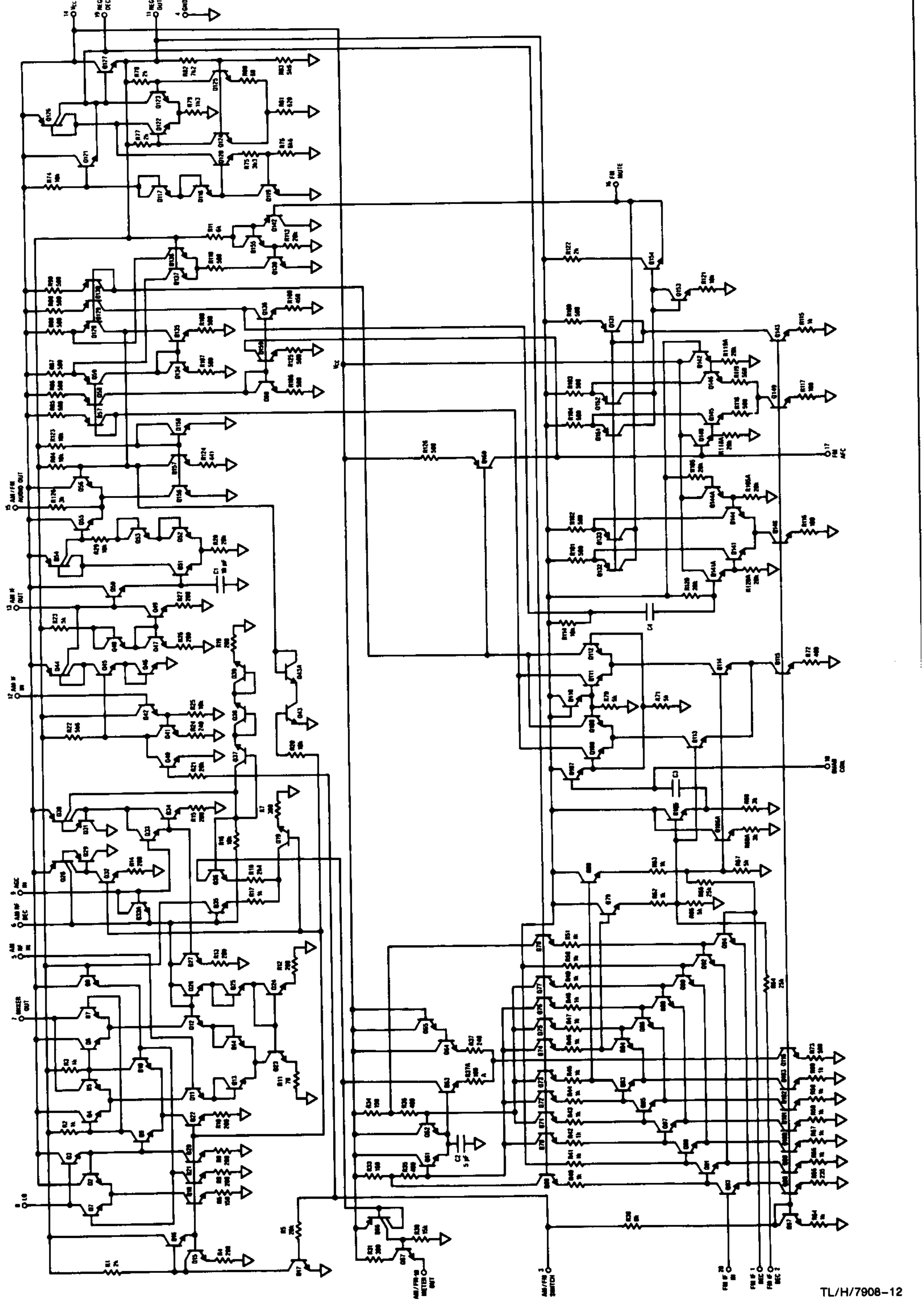


*Tweet is an audio tone produced by the 2nd and 3rd harmonic of the IF beating against the received signal. It is measured as an equivalent modulation level: i.e., a 30% tweet has the same amplitude at the detector as a desired signal with 30% modulation.

FIGURE 2. Typical AM/FM Radio Application

2

Equivalent Schematic Diagram



TL/H/7908-12