47.5 the FM Wave

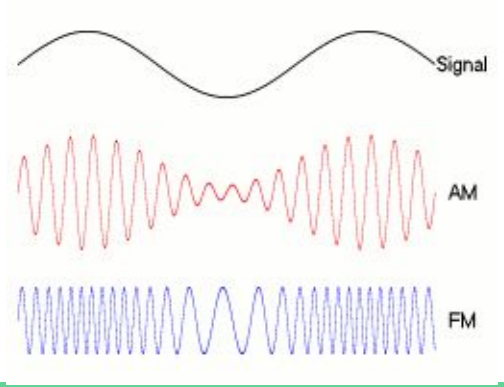
By Jenna Lidua

Background

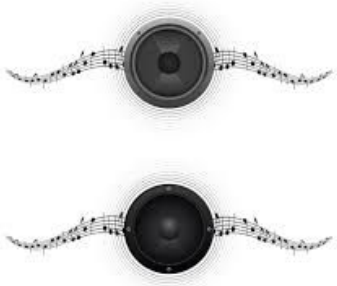
- 1830's: Radio started from wireless communication from inductive/capacitive inductance and transmission
- 1864: James Clerk Maxwell discovered electromagnetic waves (i.e. light, radio, x-rays) propagated at constant speed in free space
- 1888: Heinrich Rudolf Hertz used Maxwell's theory of electromagnetism and proved the airborne transmitted waves ("Hertzian Waves") through a frequency later became the radio spectrum
- 1906: On Christmas Eve, Reginald Fessenden produced first AM broadcast to sailors at sea ("Oh Holy Night"; Bible verse)
- 1933: Edwin H. Armstrong patented FM radio

Project Overview: FM Radio

- Need a tuner, antenna, transistors (2N3904), resistors, capacitors, Op-Amp (LM386)
- FM vs AM
  - FM has a crisper/cleaner sound, less noise
  - FM : Frequency Modulation (sound better) (88MHz - 108MHz) (Bandwidth: 200kHz per channel)
  - AM: Amplitude Modulation (heard further away) (550kHz - 1720kHz) (Bandwidth: 10kHz)
  - $\pm 10kHz$ when switching between frequency range generally

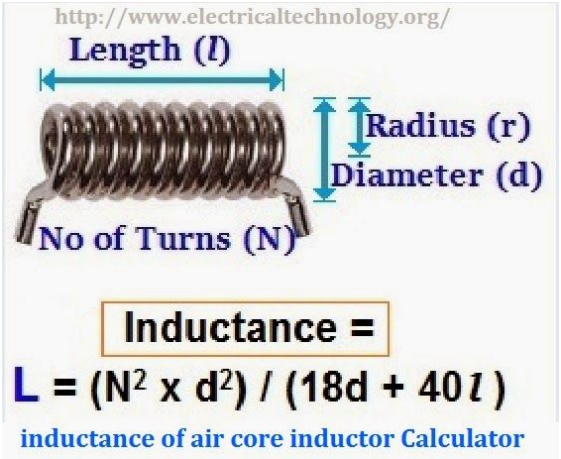


Requirements



- Target frequency: 88 - 108 MHz
- Power output from 8 ohm speaker needed: (150mW x 2) ≅300mW
  - Power output from op-amp: 250-325mW
- Variable Capacitor Range: 0.093 nF - 0.253nF

$$L = \frac{d^2 n^2}{18d + 40l} = 0.0138\ \mu H \quad ; \quad d = 0.098\ in,\ n = 4\ turns,\ l = 0.236\ in$$

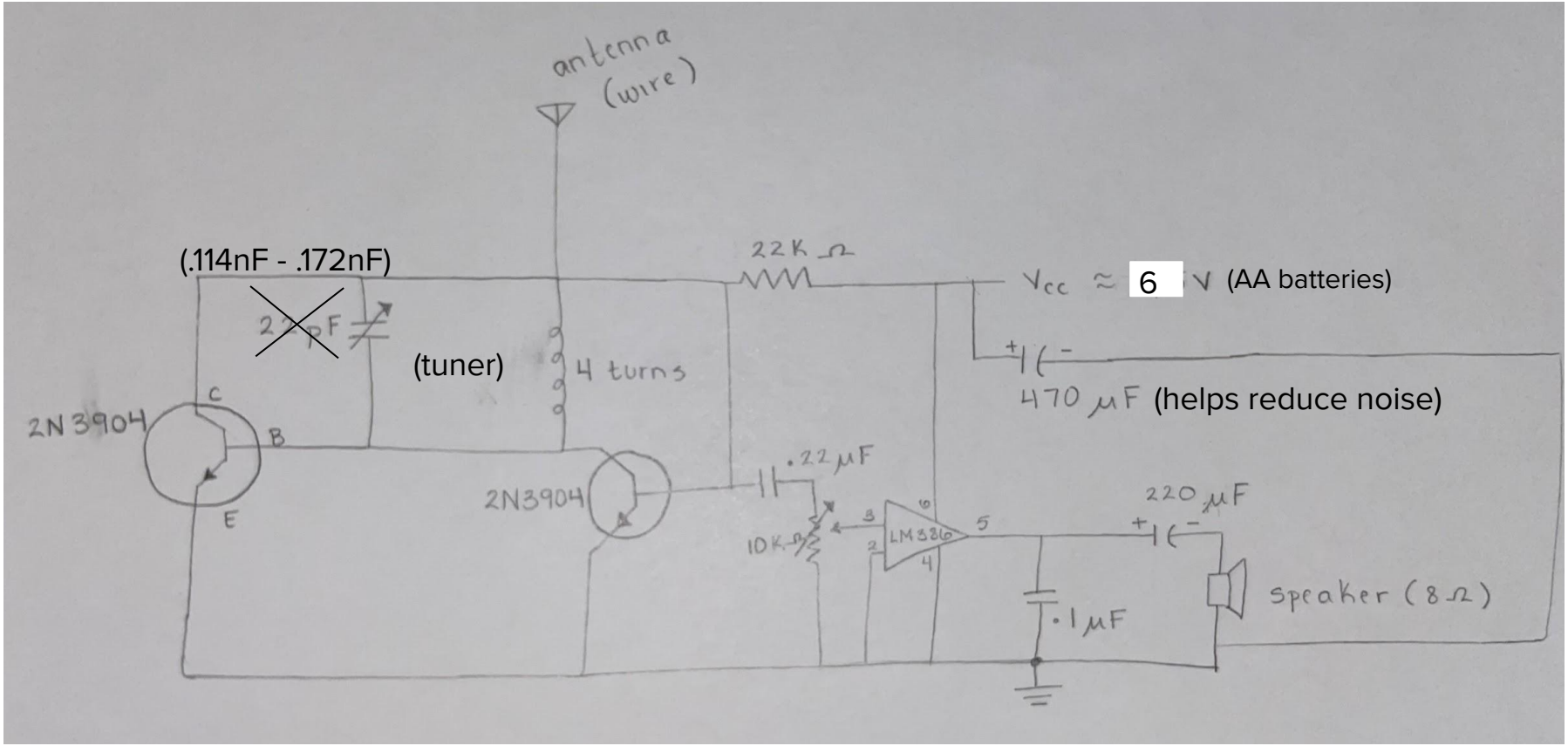


$$f = \frac{1}{2\pi\sqrt{LC}} = 88MHz\ ,\ 108MHz$$

$$C = \frac{\left(\frac{1}{2\pi(88 \cdot 10^6)}\right)^2}{L} = 0.172\ nF$$

$$C = \frac{\left(\frac{1}{2\pi(108 \cdot 10^6)}\right)^2}{L} = 0.114\ nF$$

Schematics


antenna (wire)
(.114nF - .172nF)
22K Ω
Vcc ≈ 6 V (AA batteries)
(tuner)
4 turns
2N3904
C
B
E
470 μF (helps reduce noise)
.22 μF
2N3904
10K Ω
LM386
220 μF
.1 μF
speaker (8 Ω)

Part Details: Transistor (2N3904)

2N3904

SMALL SIGNAL NPN TRANSISTOR

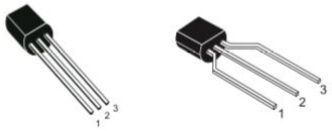
PRELIMINARY DATA

Ordering Code	Marking	Package / Shipment
2N3904	2N3904	TO-92 / Bulk
2N3904-AP	2N3904	TO-92 / Ammopack

- SILICON EPITAXIAL PLANAR NPN TRANSISTOR
- TO-92 PACKAGE SUITABLE FOR THROUGH-HOLE PCB ASSEMBLY
- THE PNP COMPLEMENTARY TYPE IS 2N3906

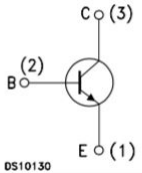
APPLICATIONS

- WELL SUITABLE FOR TV AND HOME APPLIANCE EQUIPMENT
- SMALL LOAD SWITCH TRANSISTOR WITH HIGH GAIN AND LOW SATURATION VOLTAGE



TO-92 Bulk **TO-92 Ammopack**

INTERNAL SCHEMATIC DIAGRAM



DS10130

ABSOLUTE MAXIMUM RATINGS

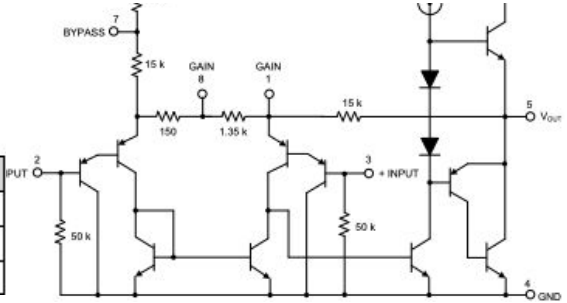
Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage (I_E = 0)	60	V
V_{CEO}	Collector-Emitter Voltage (I_B = 0)	40	V
V_{EBO}	Emitter-Base Voltage (I_C = 0)	6	V
I_C	Collector Current	200	mA
P_{tot}	Total Dissipation at T_C = 25 °C	625	mW
T_{stg}	Storage Temperature	-65 to 150	°C
T_j	Max. Operating Junction Temperature	150	°C

Part Details: Op-Amp (LM386)

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_{CC}	Supply Voltage	4		12	V
	LM386N-4	5		18	V
	Speaker Impedance	4			Ω



6.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_S	Operating Supply Voltage	LM386N-1, -3, LM386M-1, LM386MM-1	4		12	V
		LM386N-4	5		18	
I_Q	Quiescent Current	V_S = 6 V, V_{IN} = 0		4	8	mA
P_{OUT}	Output Power	V_S = 6 V, R_L = 8 Ω, THD = 10% (LM386N-1, LM386M-1, LM386MM-1)	250	325		mW
		V_S = 9 V, R_L = 8 Ω, THD = 10% (LM386N-3)	500	700		
		V_S = 16 V, R_L = 32 Ω, THD = 10% (LM386N-4)	700	100		
A_V	Voltage Gain	V_S = 6 V, f = 1 kHz		26		dB
		10 µF from Pin 1 to 8		46		
BW	Bandwidth	V_S = 6 V, Pins 1 and 8 Open		300		kHz
THD	Total Harmonic Distortion	V_S = 6 V, R_L = 8 Ω, POUT = 125 mW f = 1 kHz, Pins 1 and 8 Open		0.2%		
PSRR	Power Supply Rejection Ratio	V_S = 6 V, f = 1 kHz, CBYPASS = 10 µF Pins 1 and 8 Open, Referred to Output		50		dB
R_{IN}	Input Resistance			50		kΩ
I_{BIAS}	Input Bias Current	V_S = 6 V, Pins 2 and 3 Open		250		nA

2 Applications

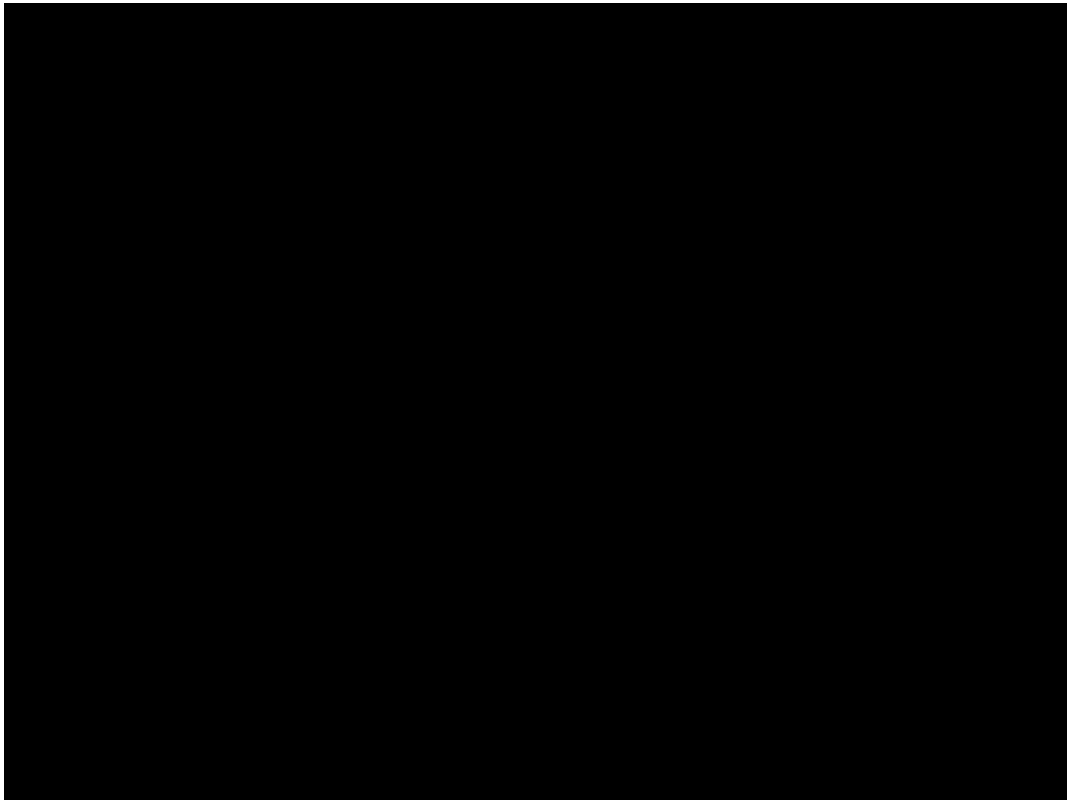
- AM-FM Radio Amplifiers
- Portable Tape Player Amplifiers

3 Description

The LM386M-1 and LM386MX-1 are power amplifiers designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value from 20 to 200.

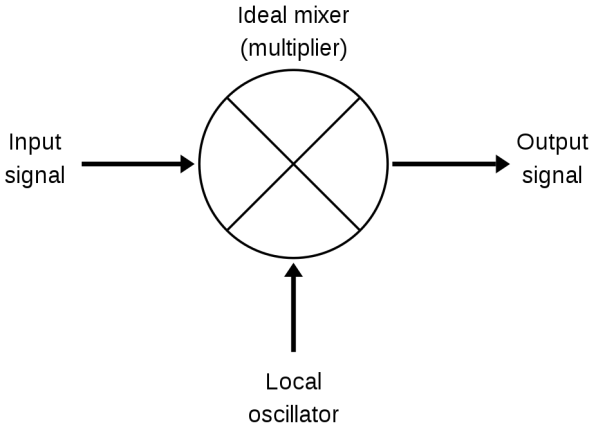
The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 mW when operating from a 6-V supply, making the LM386M-1 and LM386MX-1 ideal for battery operation.

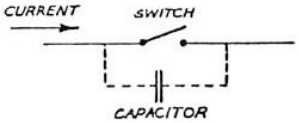
Demo Video



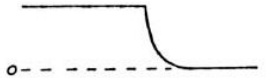
Learned?

- How a tuner works: capacitor, inductor, frequency
- Difference between AM and FM
- Trial and Error with electronics
- Noise Causes/Reduction:
  - Electronics w/in 20 feet causes disruption (white noise/static)
  - VHF radio reception limited to 30-40 miles
  - Adding more precise antenna
  - Frequency mixer: creates new frequencies from two signals
  - Adding capacitor from Vcc to speaker/ground





NO CAPACITOR
– CURRENT FALLS RAPIDLY TO ZERO WHEN SWITCH IS OPENED CREATING SERIOUS INTERFERENCE.



CAPACITOR ACROSS CONTACTS
– CURRENT FALLS SLOWLY TO ZERO WHEN SWITCH IS OPENED RESULTING IN LESS INTERFERENCE.

References

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- https://flypaper.soundfly.com/discover/what-actually-is-the-difference-between-am-and-fm-radio/
- Datasheets:
  - https://www.sparkfun.com/datasheets/Components/2N3904.pdf
  - https://www.ti.com/lit/ds/symlink/lm386.pdf?ts=1606969103449&ref_url=https%253A%252F%252Fwww.google.com%252F
  - https://www.sony.com/electronics/support/res/manuals/2899/28993612M.pdf


Questions..?