

Lecture 03 - **TOPOLOGIES**

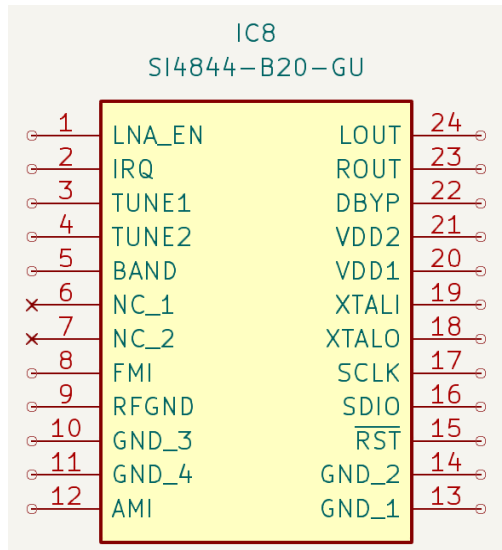
Common electrical topologies (1/2)

Outline

- **Some ECAD notes**
- **Introduction**
- **Antenna**
- **RF Amplifier**
- **Audio Amplifier and speakers**
- **FM Receiver Application Circuit**
- **Summary**

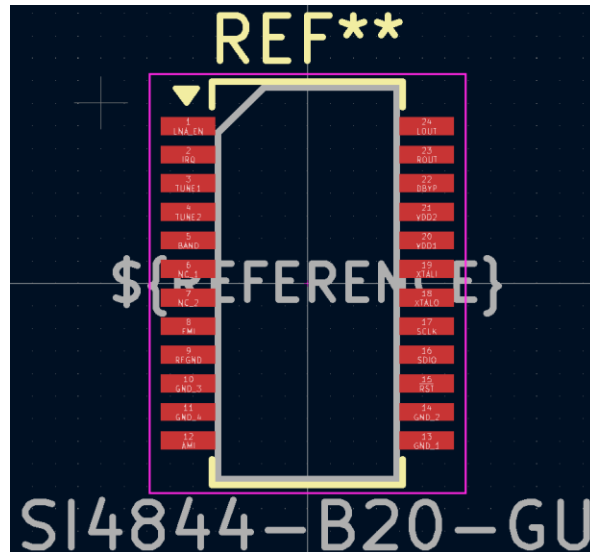
ECAD Flow

Symbols and Footprints



Symbol (goes on schematic)

- Used to specify electrical connections between components

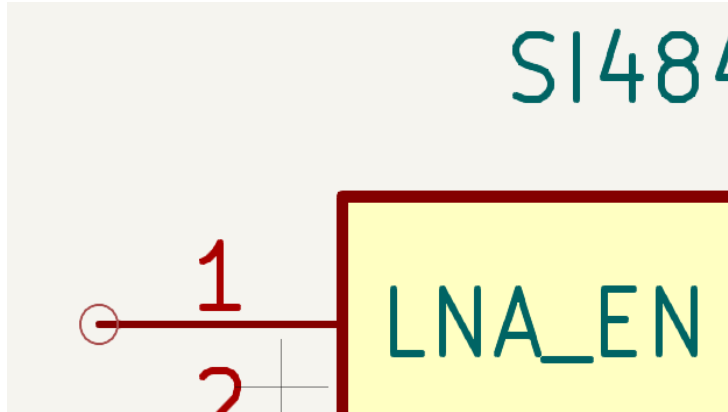


Footprint (goes on layout)

- Specifies copper and the physical manner in which the part attaches to the board

ECAD Flow

Pins and Pads



Pin → Pad

These get mapped to each other using **pin/pad number**

Nets

What are they?

- A net another word for node
- It is a "point" that components can be connected to
- Let's take a look at how our tools represent nets behind the scenes



Nets

Behind the scenes

N004; U1.1 R4.2 R5.1
N001; U1.2 R2.1 R6.2
vcc; U1.3 V1.1 C2.2 R3.1,
R4.1
0; U1.4 V1.2 V2.2 C2.1,
R5.2 R7.2
amp_out; U1.5 R6.1 C3.2
N005; U1.6 R3.2
N002; V2.1 R1.2
vin; R1.1 C1.2
N003; C1.1 R2.2
vout; C3.1 R7.1

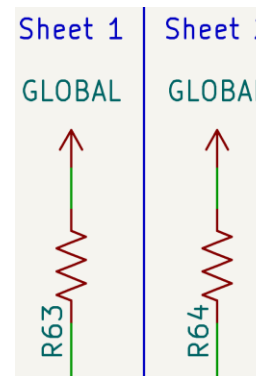
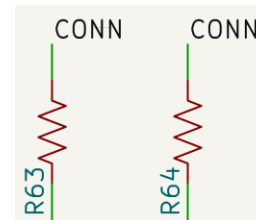
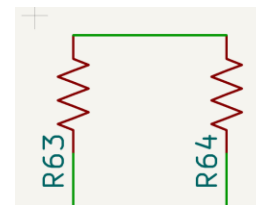
An Allegro netlist

- **Connectivity specified by netlist**
- **Many different netlist formats**
- **This one is a bit more readable**
- **It consists of a netname (e.x. N004) followed by all of the pins connected to that net**
- **The graphical schematics are for our convenience. In the end, it boils down to a netlist**

Nets

Methods of connecting symbols

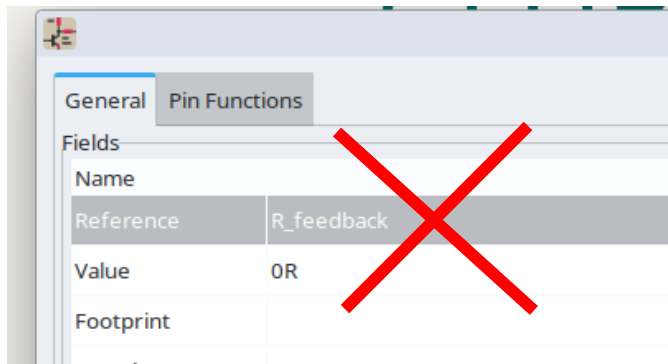
- **Wires:** What you expect. The net connection matches the graphical connection
- **Net labels:** Anything within the same sheet that shares the same net label is connected
- **Global power symbols:** Any global power symbol anywhere that shares the same name is connected
Net labels v.s. global power symbols is analogous to local variables vs global variables in programming



Reference Designators

Don't touch them!

- Reference designators will be handled through the tool in later labs
- Don't manually set a reference designator
- Weird things happen if they're not unique



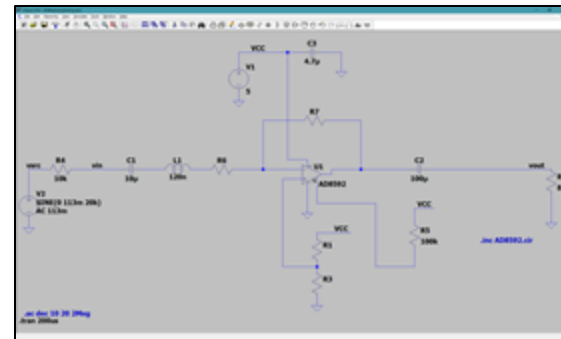
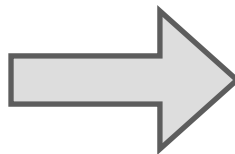
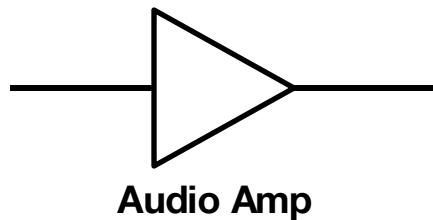
Introduction

Implementing Circuits

We've talked system-level design and discussed selecting components

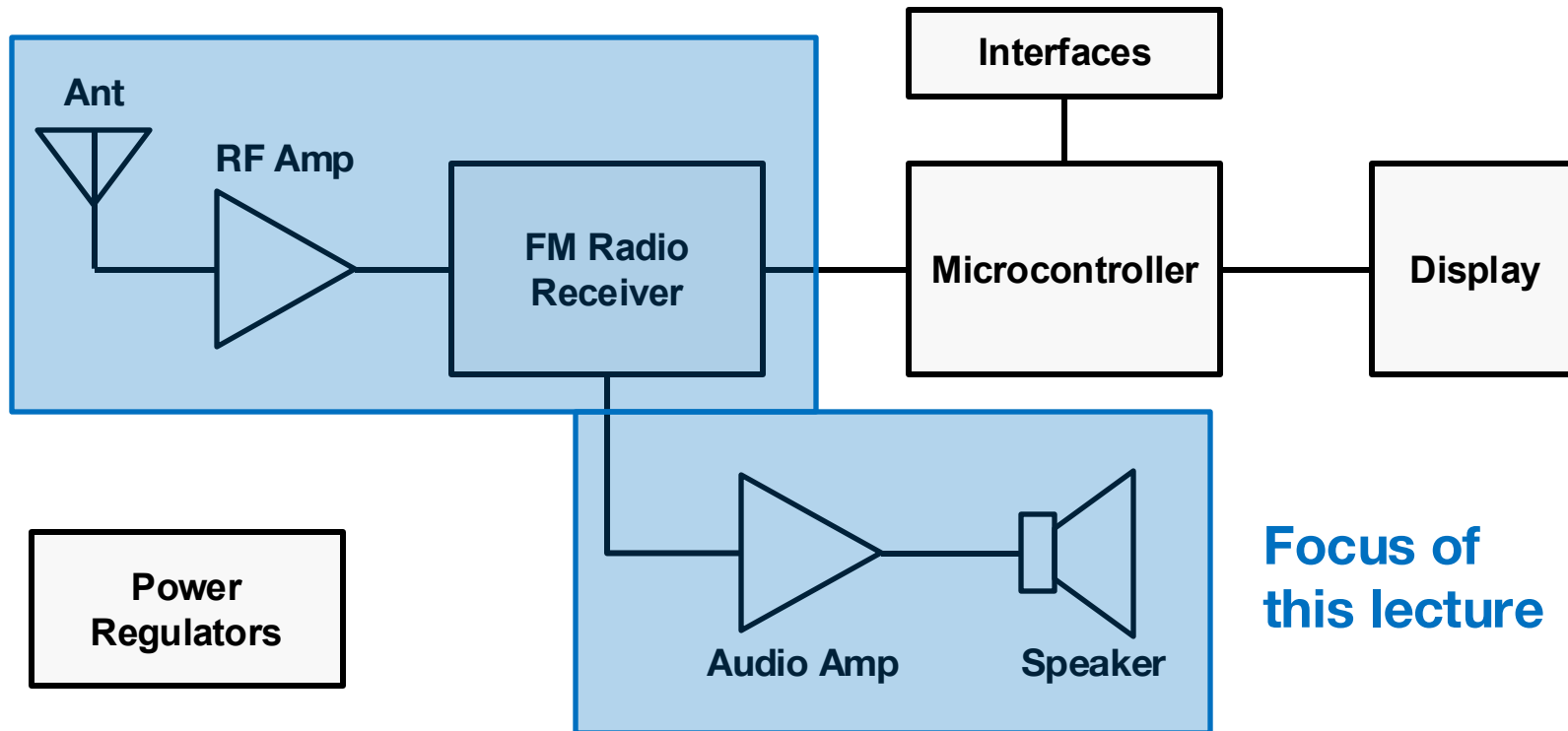
That leads us to our most important part: designing our circuits!

As you just
completed in
lab 02:



Block Diagram

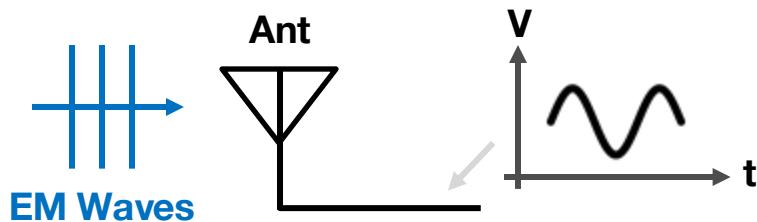
FM Radio Course Project



**Focus of
this lecture**

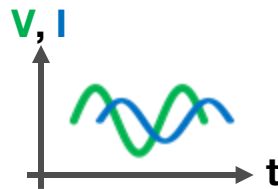
Antenna

Receiving Radio Signals



The FM radio signals travel as EM waves
When they reach our antenna, they induce currents which then enter our radio circuit

The ratio between the voltage and current wave exiting the antenna determines the impedance of the antenna



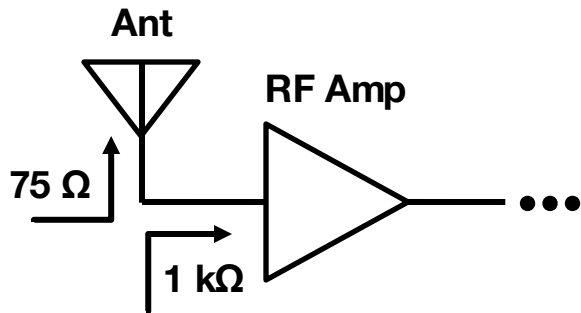
About 75 Ohms for a half-wavelength antenna



To ensure maximum power transfer between the antenna and the radio, the antenna impedance and the radio's input impedance must match

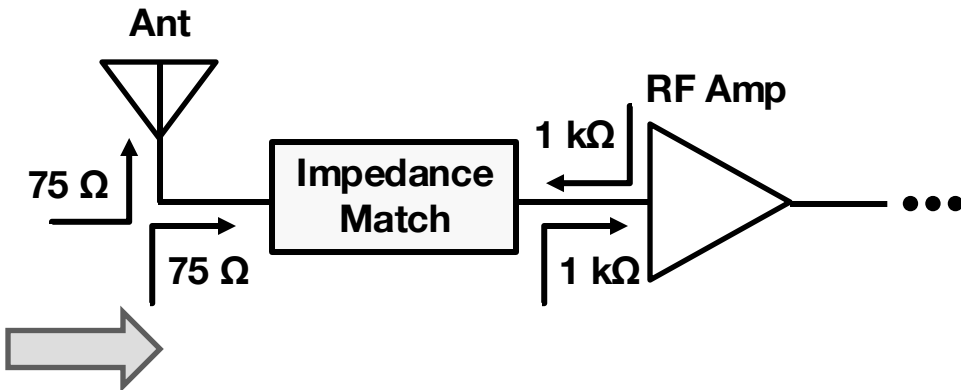
Antenna

Impedance Matching

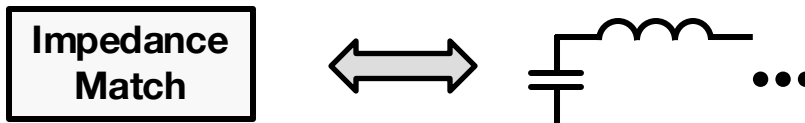


The large impedance mismatch will cause a reflection (voltages and currents don't align)

Reflections result in power loss



An impedance matching network can be used. The network transforms one impedance to another in order to ensure maximum power transfer

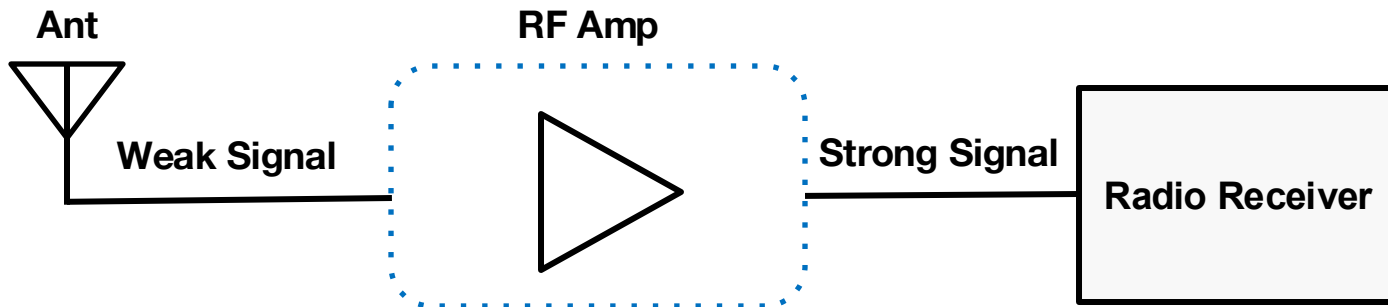


Can be done with L-C networks (L-matching or pi-matching)

RF Amplifier

Goal

- The signal picked up by our antenna is weak, so our first block needs to amplify this signal before it goes to the receiver



RF Amplifier

Constraints

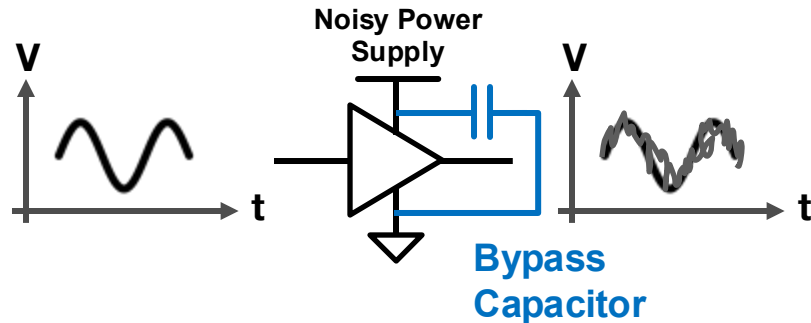
High-frequency RF signals are more sensitive to circuit details and parasitic compared systems that work closer to DC.

FM broadcast radio operates at 100MHz so we must account for:

- Noise
- Linearity
- Bandwidth

Failing to take these parameters into account will result in poor performance

Noise consists of random variations in current/voltage



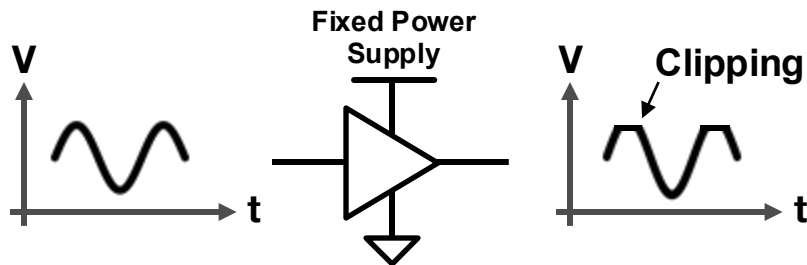
Noise Contributors:

- Resistors/lossy devices (think thermal noise)
- Unshielded areas (EMI) or coupling of external fields
- Switching-based devices with poor oscillators (buck/boost converters)

RF Amplifier

Constraints

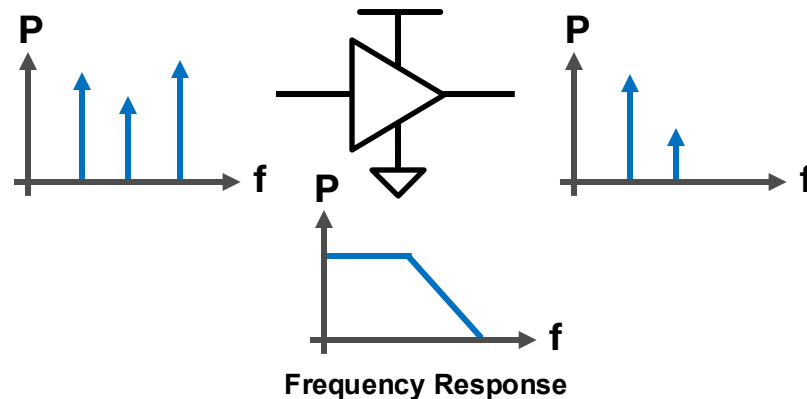
Linearity determines how wide the input/output swing can be



Often this is due to constraints in the supply voltage (lab 02)

A very high or low output voltage can un-bias a device, causing clipping

Bandwidth determines our frequency operating range



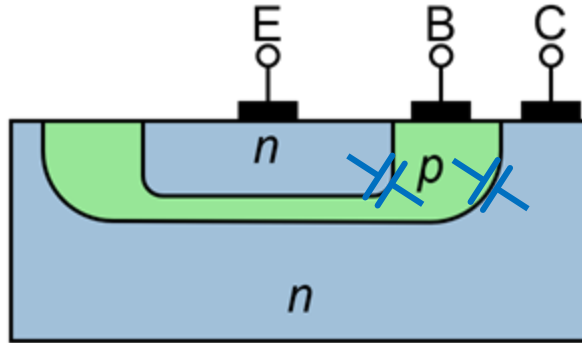
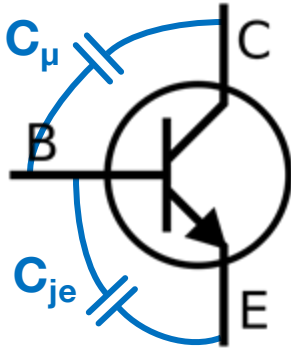
Parasitics (unwanted R_s , L_s , and C_s) create parasitic filter networks which reduce bandwidth

RF Amplifier

Parasitics

How parasitics affect our circuits depends on the topologies that we choose

- Most modern amplifiers are built from transistors

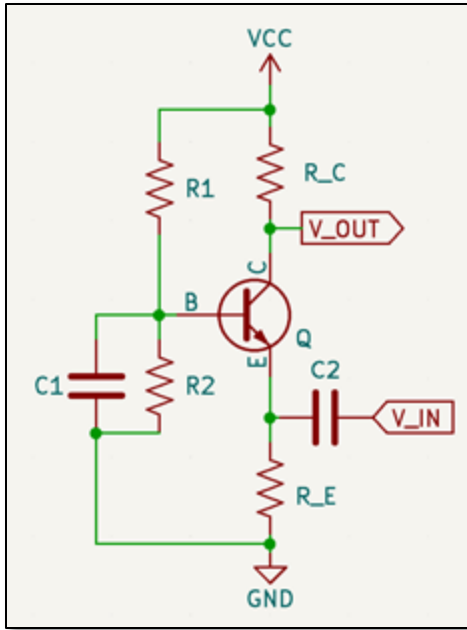


- If we reduce our transistor usage, we reduce our parasitics

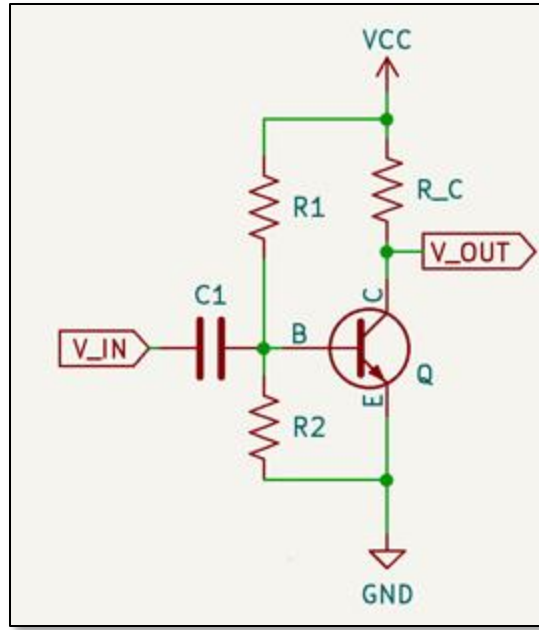
RF Amplifier

BJT Amplifier Topologies

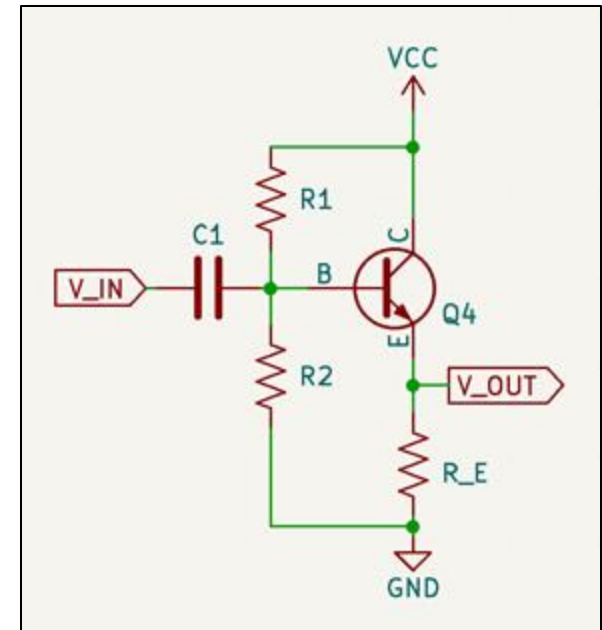
Common Base



Common Emitter



Common Collector



RF Amplifier

BJT Amplifier Topologies

Common Base

- Current gain ~ 1
- High voltage gain
- Low input impedance
- Higher bandwidth

Common Emitter

- High current gain
- High voltage gain
- Medium input impedance
- Lower bandwidth (Miller effect)

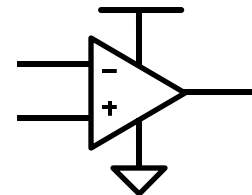
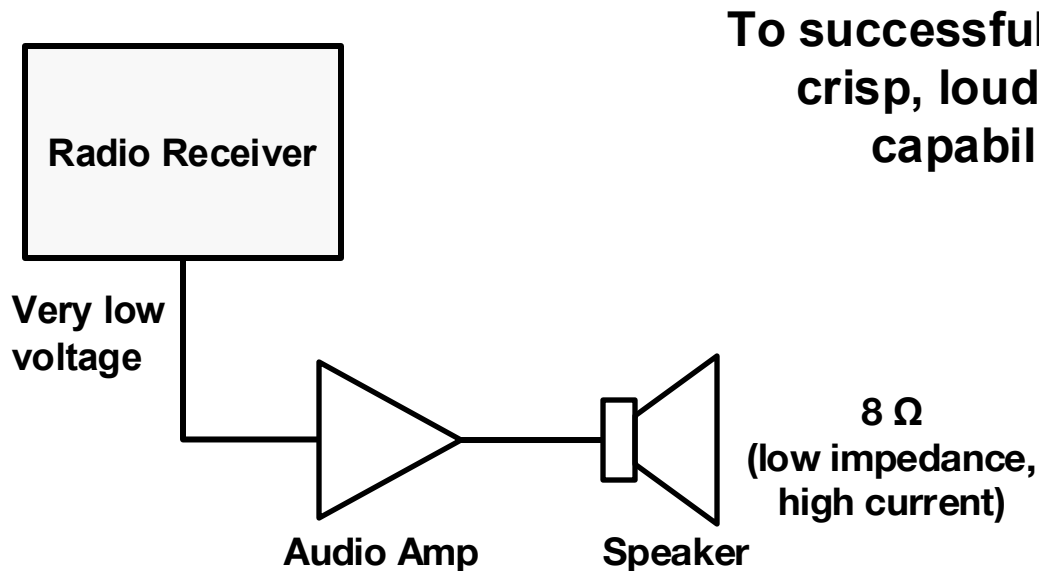
Common Collector

- High current gain
- Voltage gain ~ 1
- High input impedance

Which topology should we use for the FM radio?

Audio Amplifier

Goal



Perhaps an op amp?

Audio Amplifier

As seen in Lab 2!

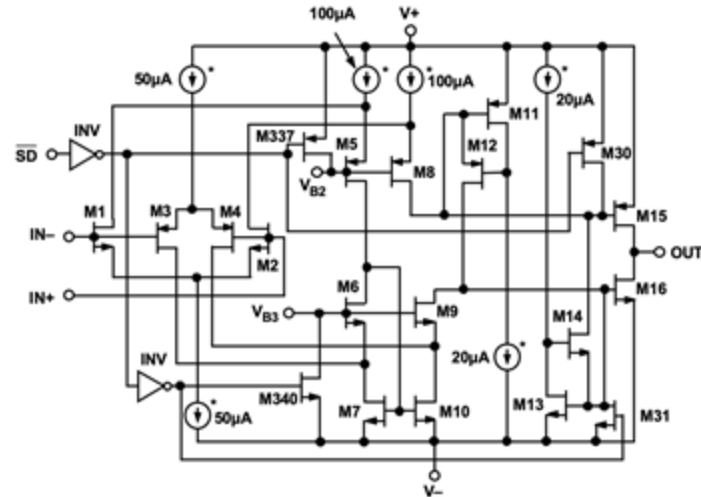
For more standard, lower frequency use-cases (where we are less bandwidth and noise constrained) we construct amplifiers using op-amps

- High gain
- Differential Input
- Versatile configurations
- High input impedance + low output impedance
- Nicely packaged as ICs



**AD8592 IC
Pinout**

High transistor count = noisy
= lower bandwidth



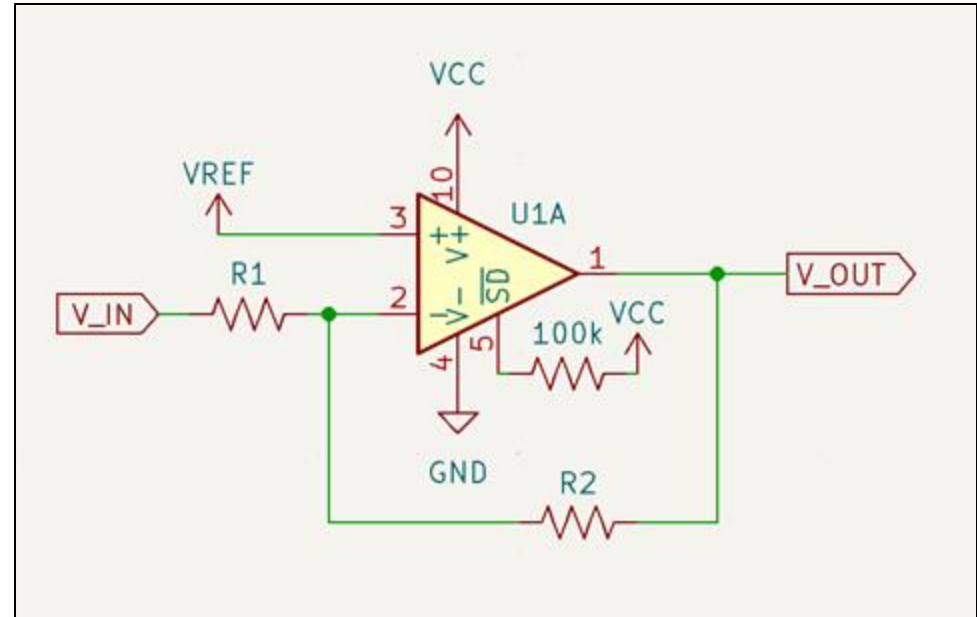
**AD8592
Simplified
Schematic**

Audio Amplifier

Schematic

Inverting op-amp topology:

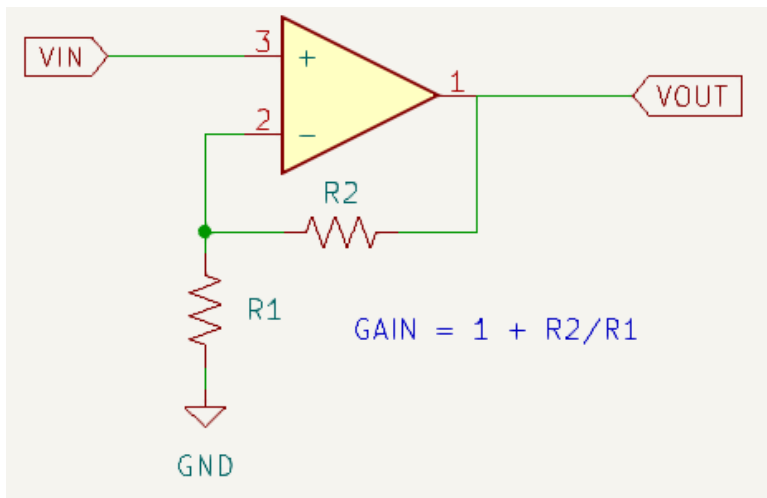
- Input signal goes into inverting (negative) op-amp input
- Noninverting (positive) op-amp input tied to DC offset voltage
- Gain = $-R2/R1$
- 180 degree phase shift
- VREF sets output DC bias



Audio Amplifier

Aside: Non-inverting Op-amps

Why do we use an inverting topology instead of a noninverting topology?



Non-inverting amplifier

Noninverting topology:

- Input signal feeds directly into the op-amp
- Very high input impedance

Inverting topology:

- Input impedance is controlled by the value of $R1$, which is substantially lower than the op-amp's input impedance
- Typically easier to bias

Audio Amplifier

A more practical solution

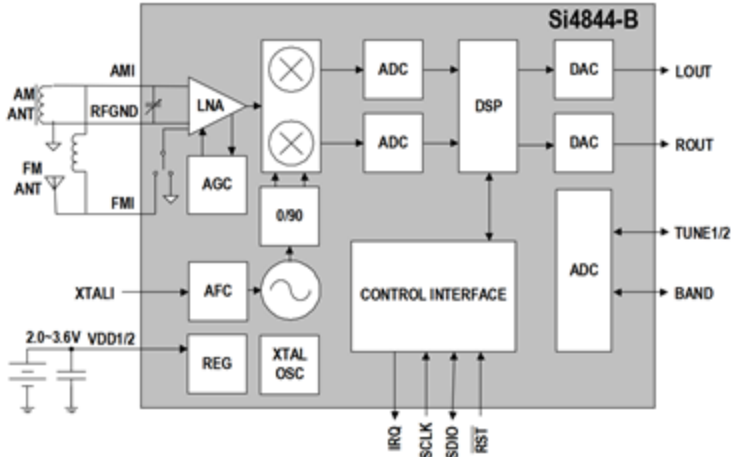


- Op-amps are cool, but they're not really intended to supply a lot of current
- (We really just wanted you to practice designing with op-amps)
- Instead, you could use an integrated amplifier like the PAM8302
- Pros: low part count, high power, efficient, cheap, easy

FM Receiver Chip

Recommended Circuit

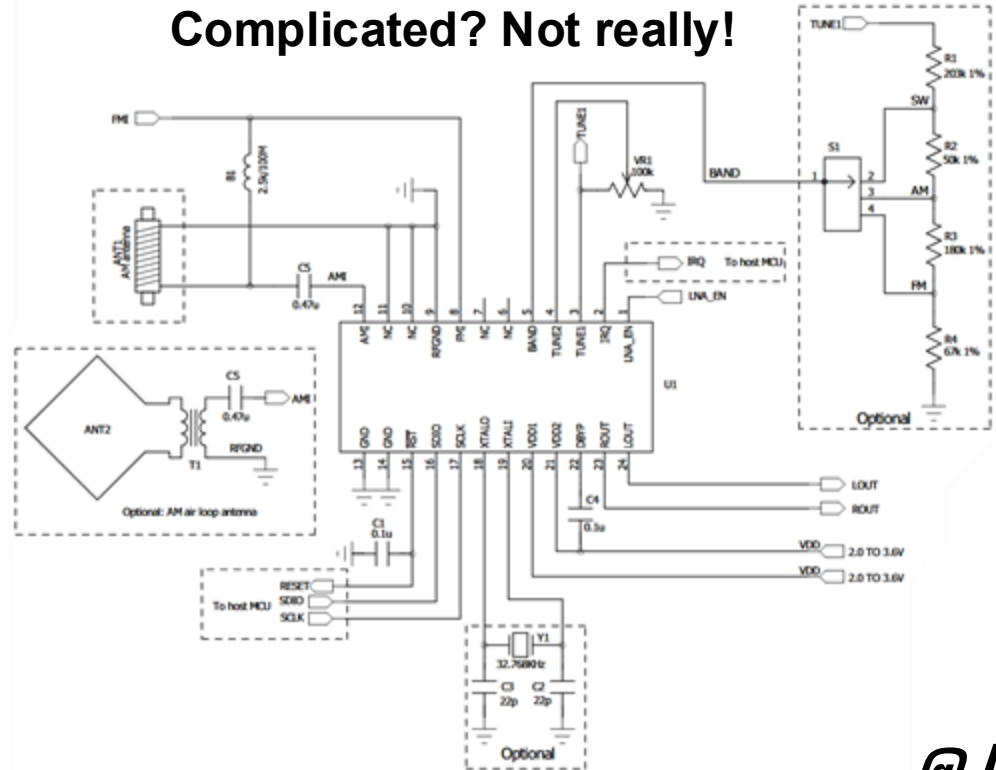
Si4844-B20



Functional Block Diagram

Typical Application Circuit

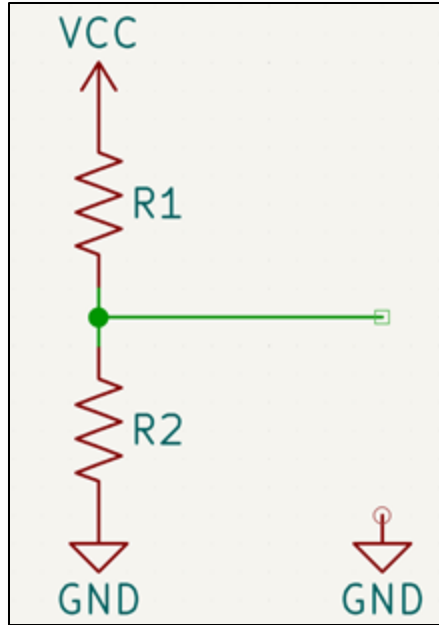
Complicated? Not really!



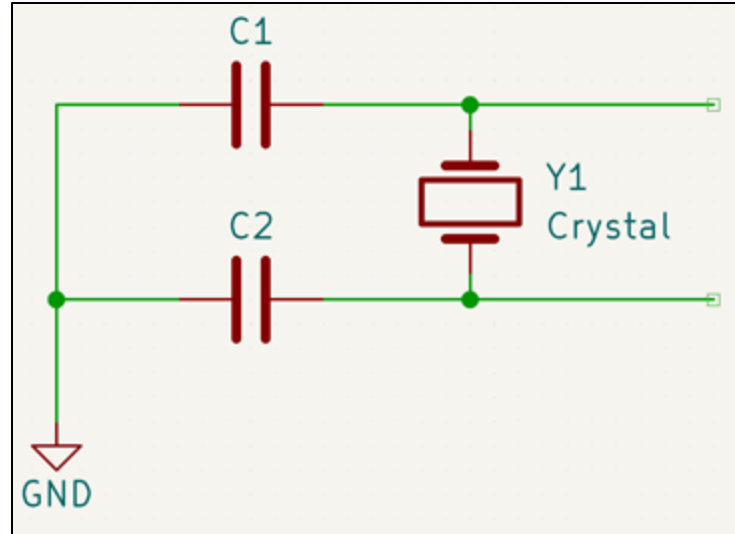
FM Receiver Chip

Typical Application Circuit

Resistor Divider



Crystal Oscillator



Questions?