Lecture 03 - TOPOLOGIES

Common electrical topologies (1/2)

Outline

- Introduction
- Antenna
- RF Amplifier
- Audio Amplifier and speakers
- FM Receiver Application Circuit
- Summary

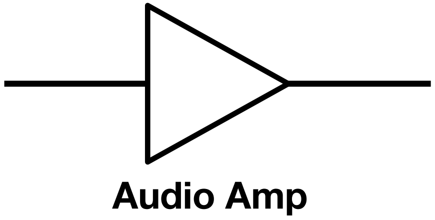
Introduction

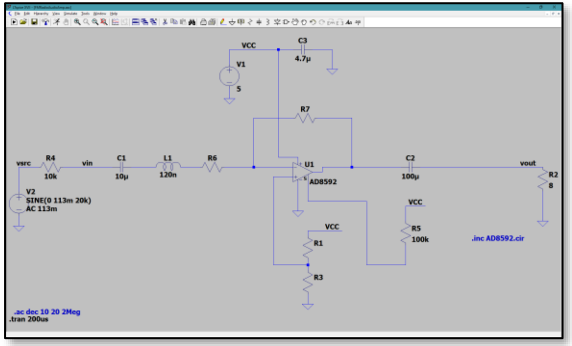
Implementing Circuits

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

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

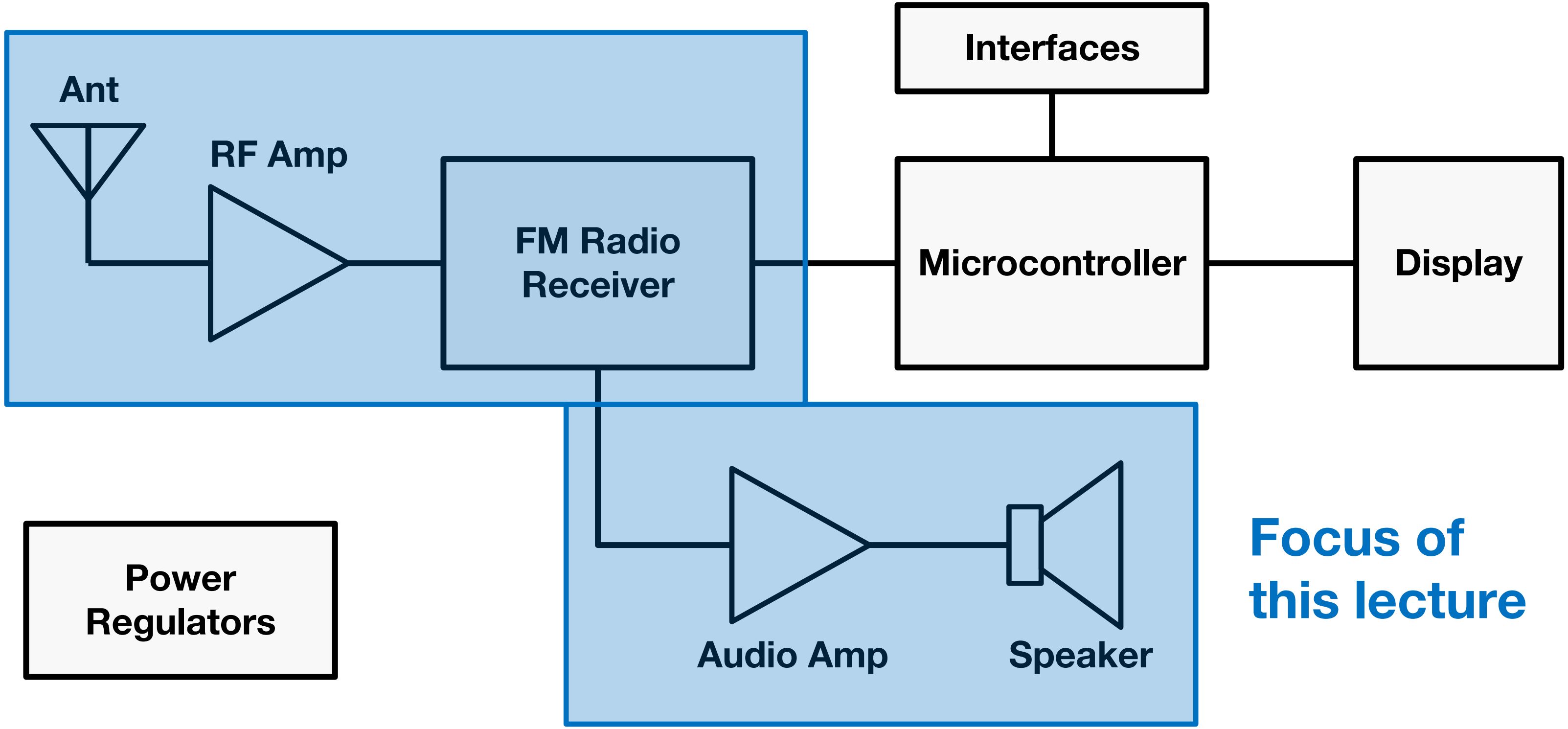
As you just completed in lab 02:





Block Diagram

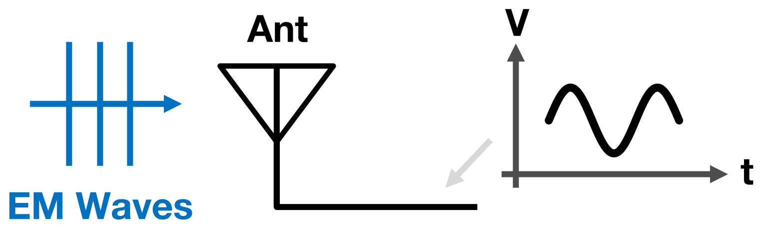
FM Radio Course Project



Focus of this lecture

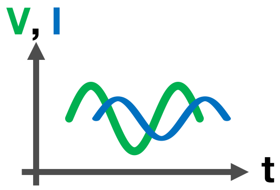
Antenna

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

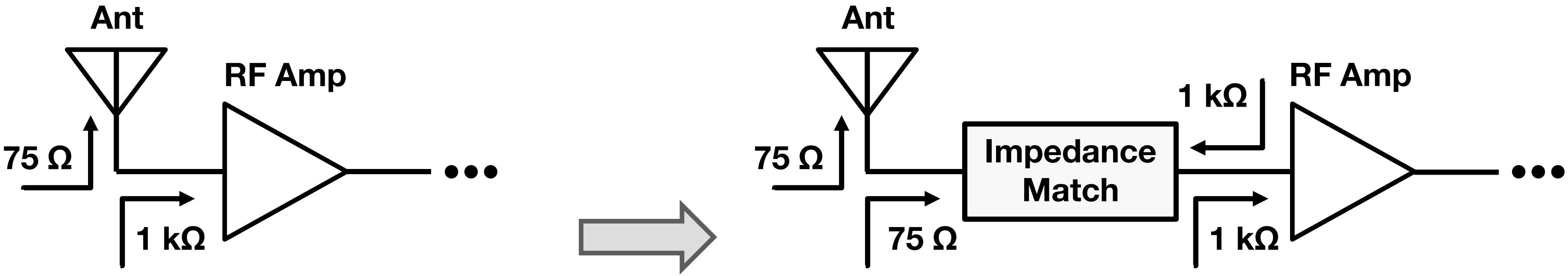


About 75 Ohms for a half-wavelength antenna

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

Antenna

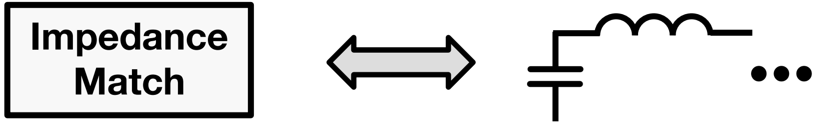
Impedance Matching



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

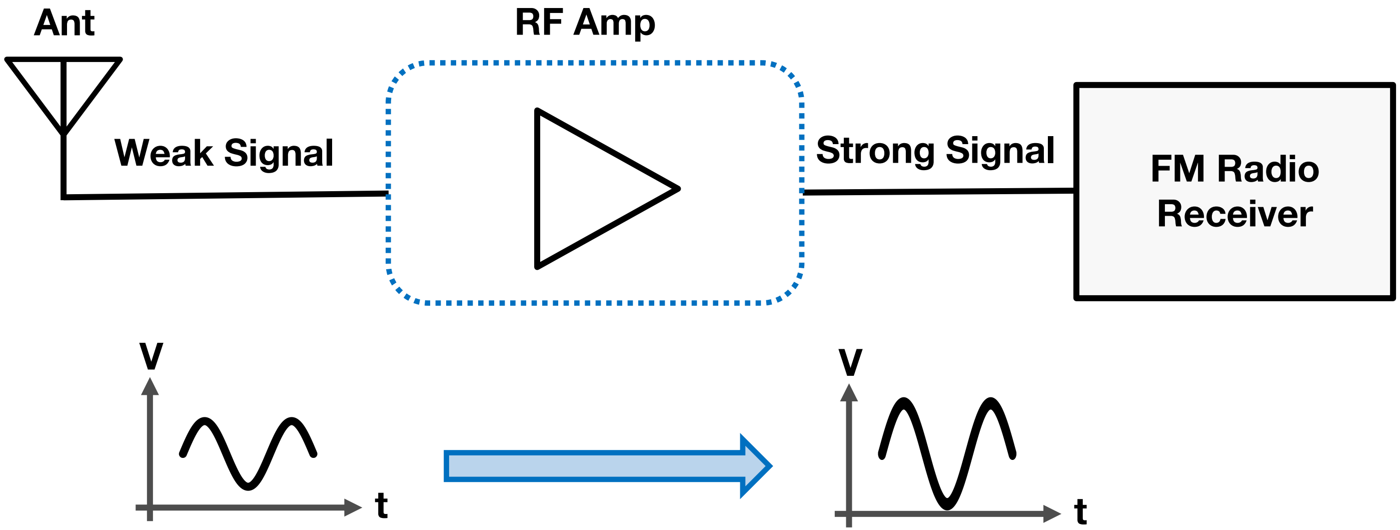


Can be done with L-C networks (L-matching or pi-matching)

RF Amplifier

Goal

- **The FM 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

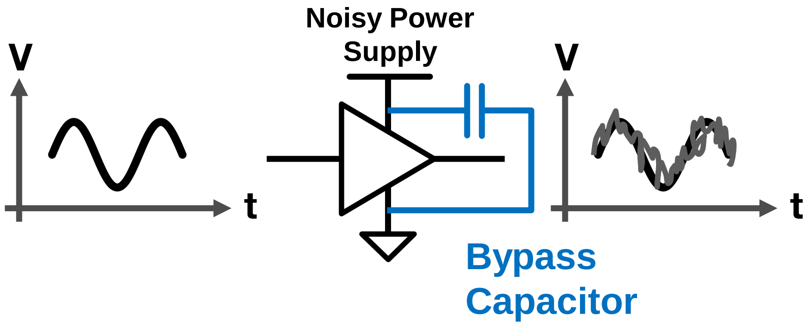
High-frequency RF signals are more sensitive to circuit details and parasitic compared systems that work closer to DC.

FM broadcast radio operates at 100 MHz, 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



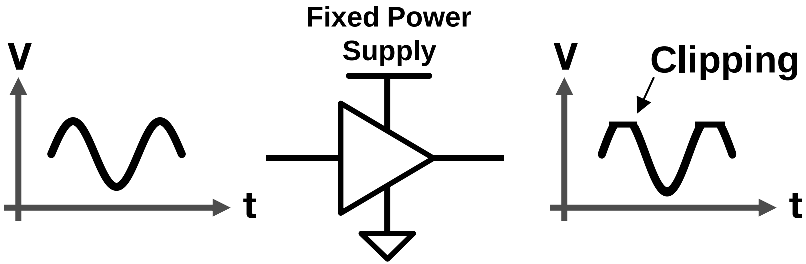
Noise Contributors:

- **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

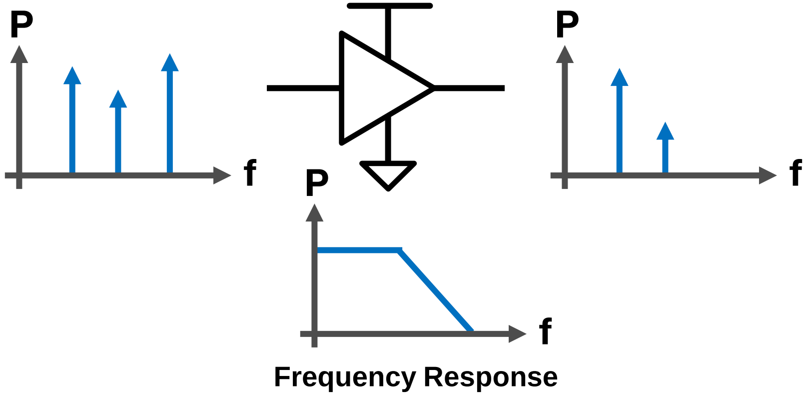
Linearity determines how wide the input/output swing can be



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 Rs, Ls, and Cs) create parasitic filter networks which reduce bandwidth

THE ART AND SCIENCE OF PCB DESIGN
IAP 2025

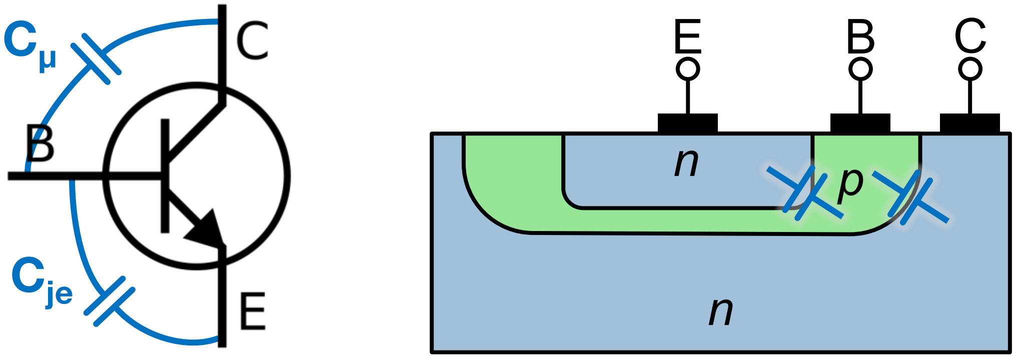
@ MIT

RF Amplifier

Parasitics

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

- **Most modern amplifiers are built from transistors**

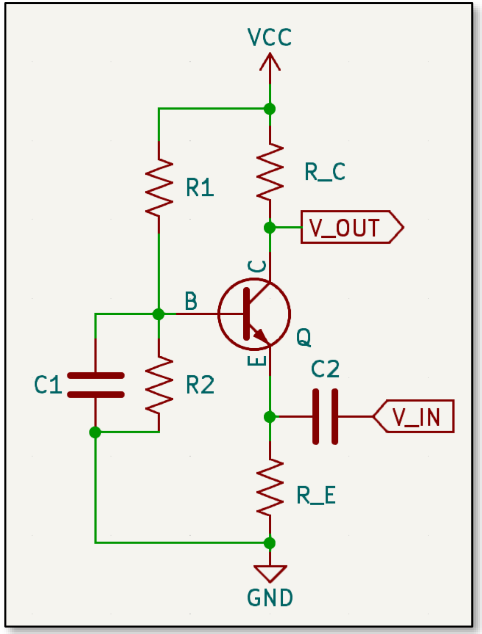


- **If we reduce our transistor usage, we reduce our parasitics**

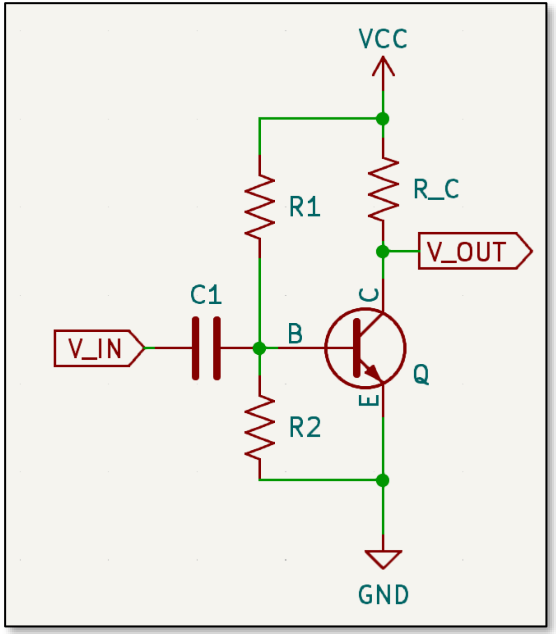
RF Amplifier

BJT Amplifier Topologies

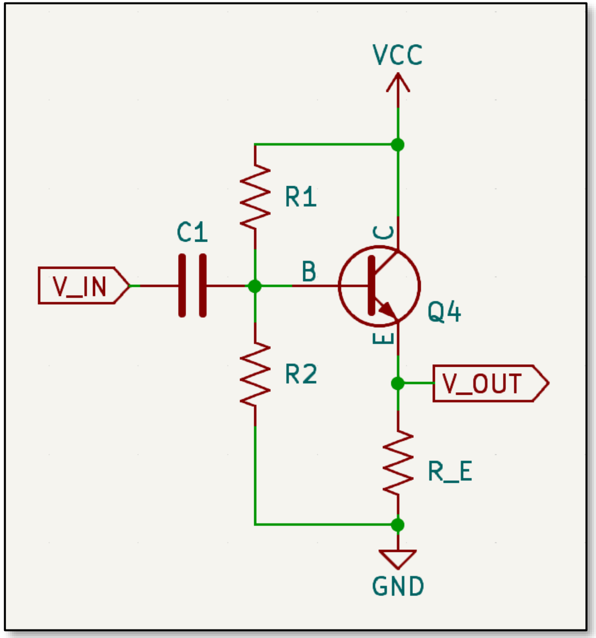
Common Base



Common Emitter



Common Collector



RF Amplifier

BJT Amplifier Topologies

THE ART AND SCIENCE OF PCB DESIGN

IAP 2025

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)

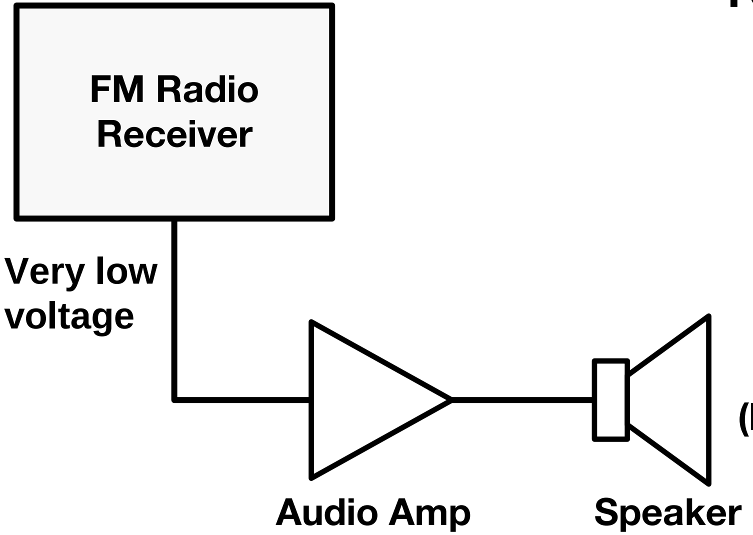
Common Collector

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

Which topology should we use for the FM radio?

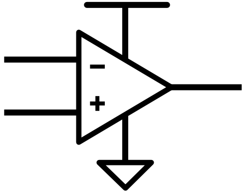
Audio Amplifier

Goal



8 Ω
(low impedance,
high current)

To successfully drive the speaker and have crisp, loud sound output we need the capability to drive high current



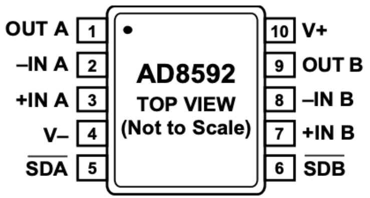
Perhaps an op amp?

Audio Amplifier

As seen in Lab 2!

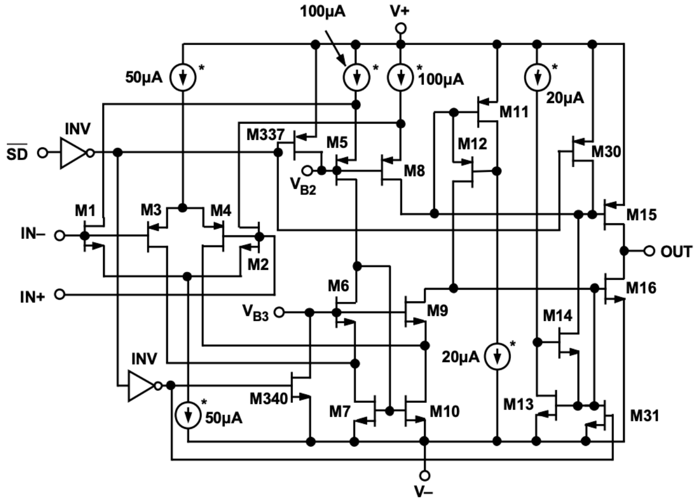
For more standard, lower frequency use-cases (where we are less bandwidth and noise constrained) we construct amplifiers using op-amps

- **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



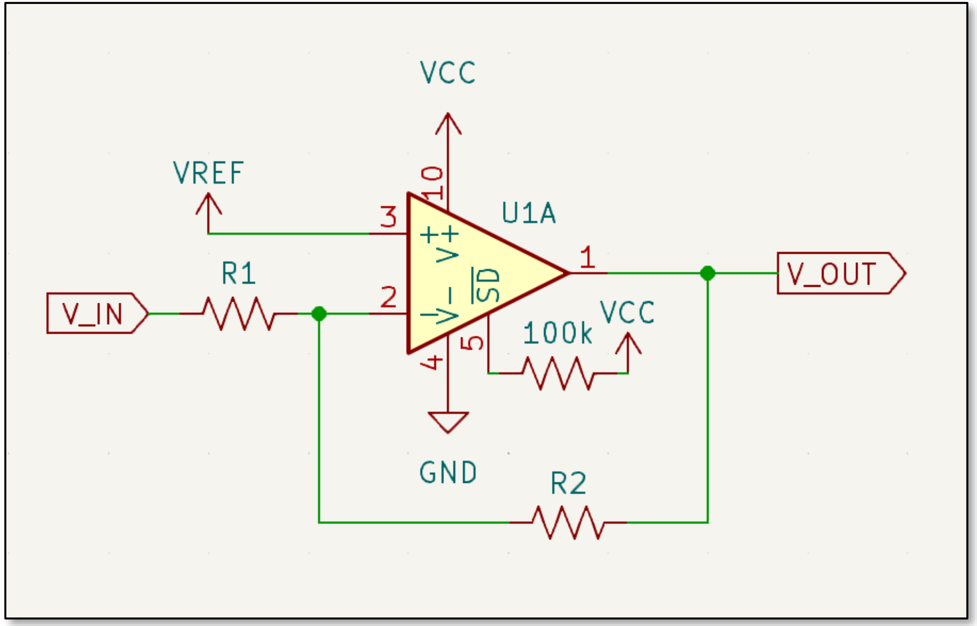
AD8592 Simplified Schematic

Audio Amplifier

Schematic

Inverting op-amp topology:

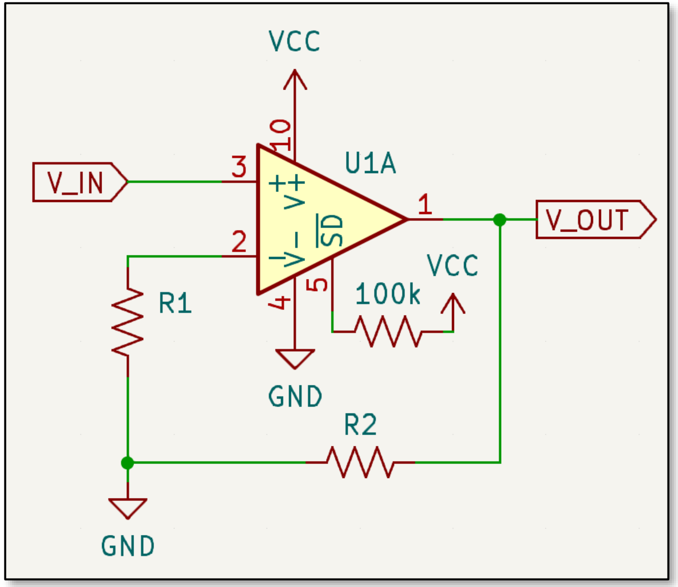
- Input signal goes into inverting (negative) op-amp input
- Noninverting (positive) op-amp input tied to DC offset voltage
- Gain = -R2/R1
- 180 degree phase shift
- VREF sets output DC bias



Audio Amplifier

Aside: Non-inverting Op-amps

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



Noninverting topology:

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

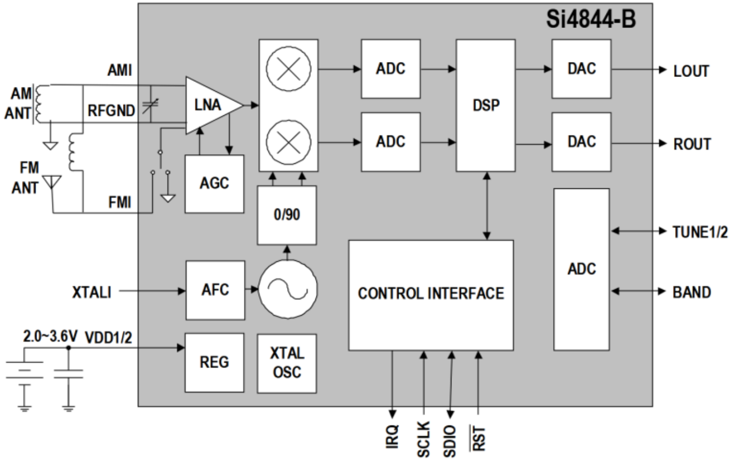
Inverting topology:

- Input impedance is controlled by the value of R1, which is substantially lower than the op-amp's input impedance
- Lower noise and higher-bandwidth

FM Receiver Chip

Recommended Circuit

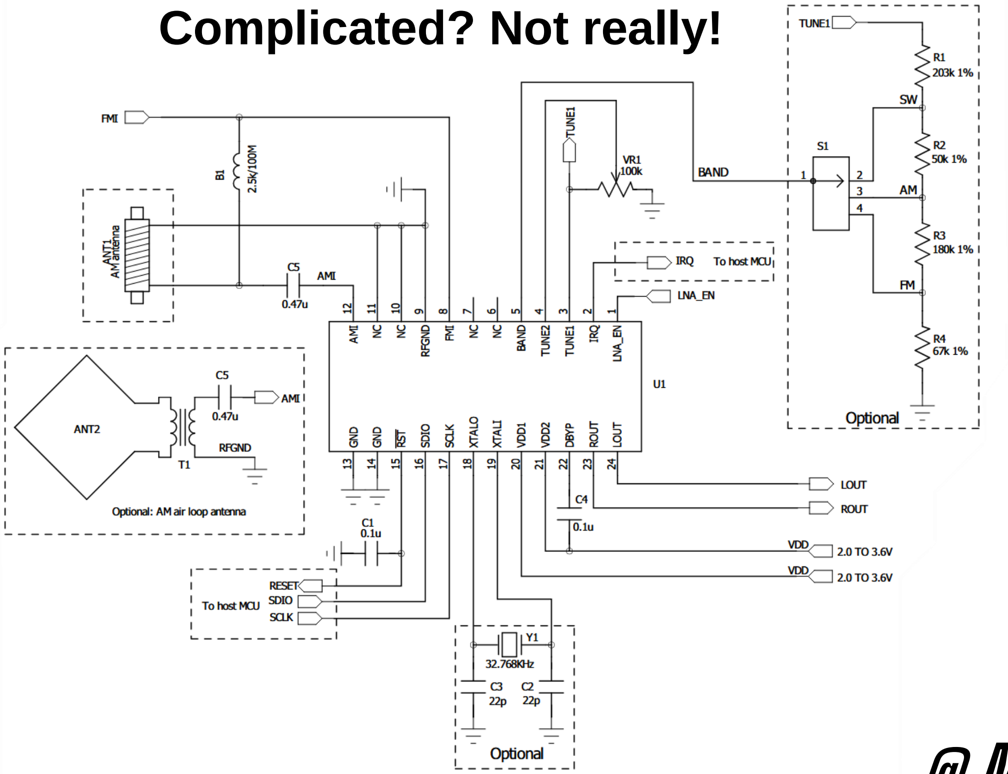
Si4844-B20



Functional Block Diagram

Typical Application Circuit

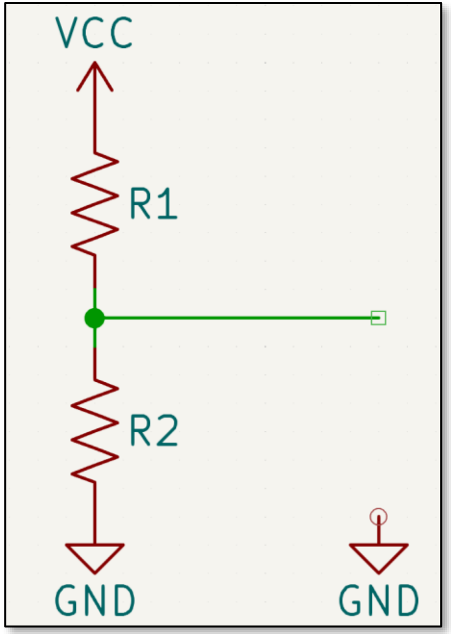
Complicated? Not really!



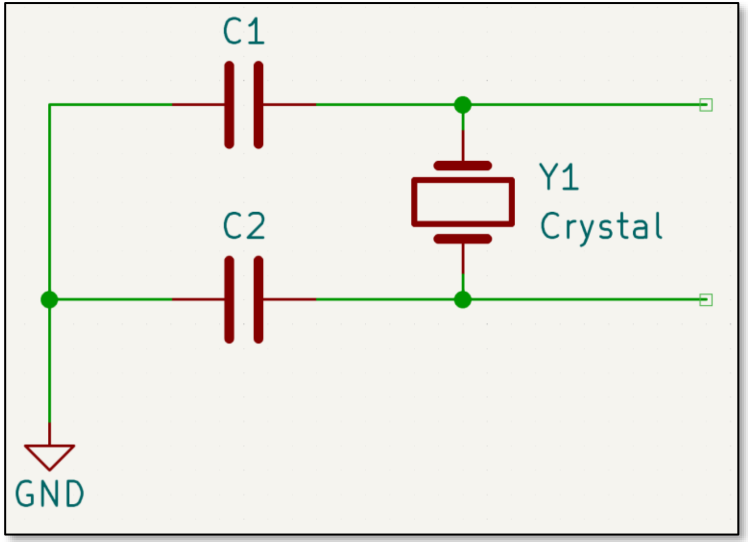
FM Receiver Chip

Typical Application Circuit

Resistor Divider



Crystal Oscillator



Questions?