Computer Logic and Digital Circuit Design (PHYS306/COSC330): Unit 1.2

Jordan Hanson

January 12, 2018

Whittier College Department of Physics and Astronomy

SUMMARY

Unit 1.2 summary - Build a radio from a pile of parts...go!

1. Introduction to *mixing* or heterodyning
   - The **transistor** plays a dual role
   - **Transistors** $\rightarrow$ forthcoming units on logic gates
2. The superheterodyne (superhet) radio receiver
3. Through-hole soldering 101
4. The DVM (digital voltmeter)
5. **Build.** $\rightarrow$ Bonus point for the first team

INTRODUCTION TO MIXING OR HETERODYNING

INTRODUCTION TO MIXING OR HETERODYNING

This is not yet *digital* circuit design. However, the **AM transistor radio** design was massively popular, taking advantage of new technology: **transistors**. Two goals are fulfilled by placing transistors in the design: mixing and amplification.

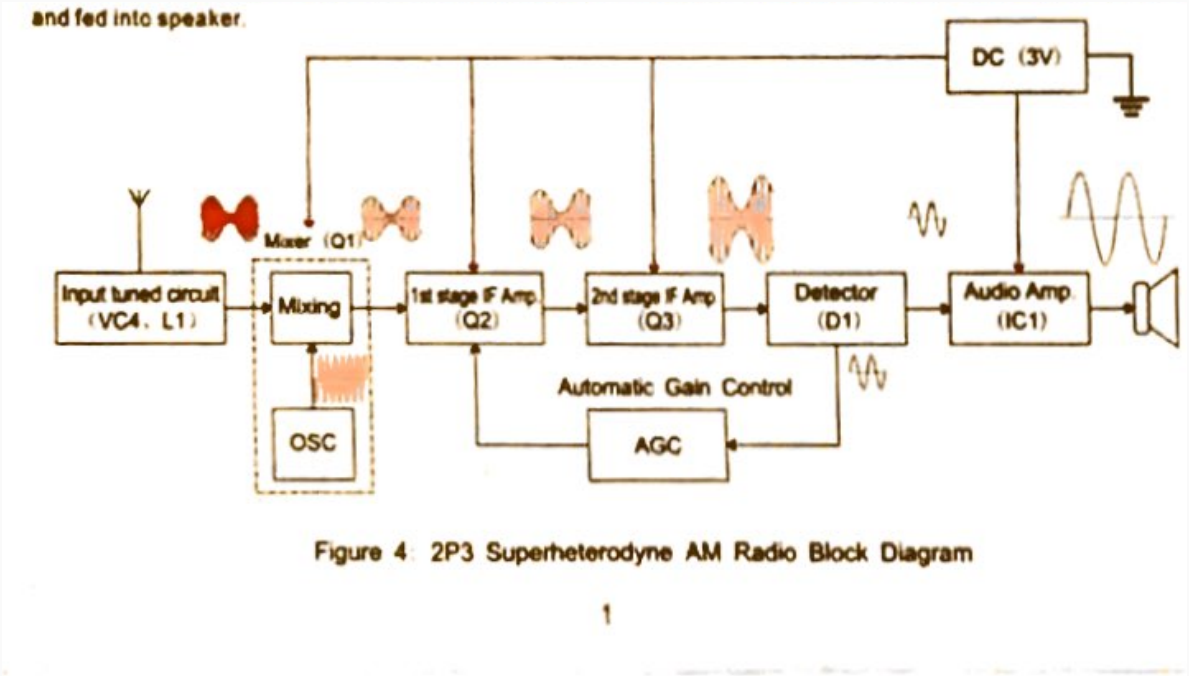


Figure 4: 2P3 Superheterodyne AM Radio Block Diagram

1

INTRODUCTION TO MIXING OR HETERODYNING

- AM radio - *amplitude modulation:* the signal data is encoded in amplitude fluctuations.
- Mixing - the concept of *beat frequencies*
- Requires stable local oscillators at fixed frequency

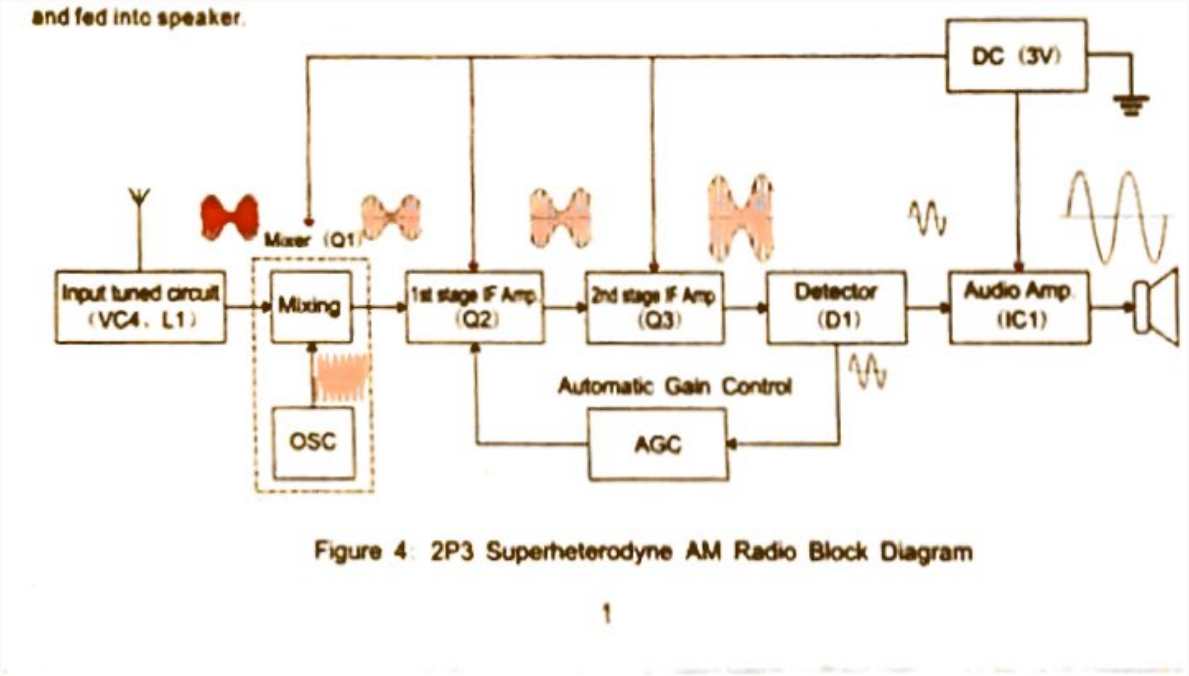
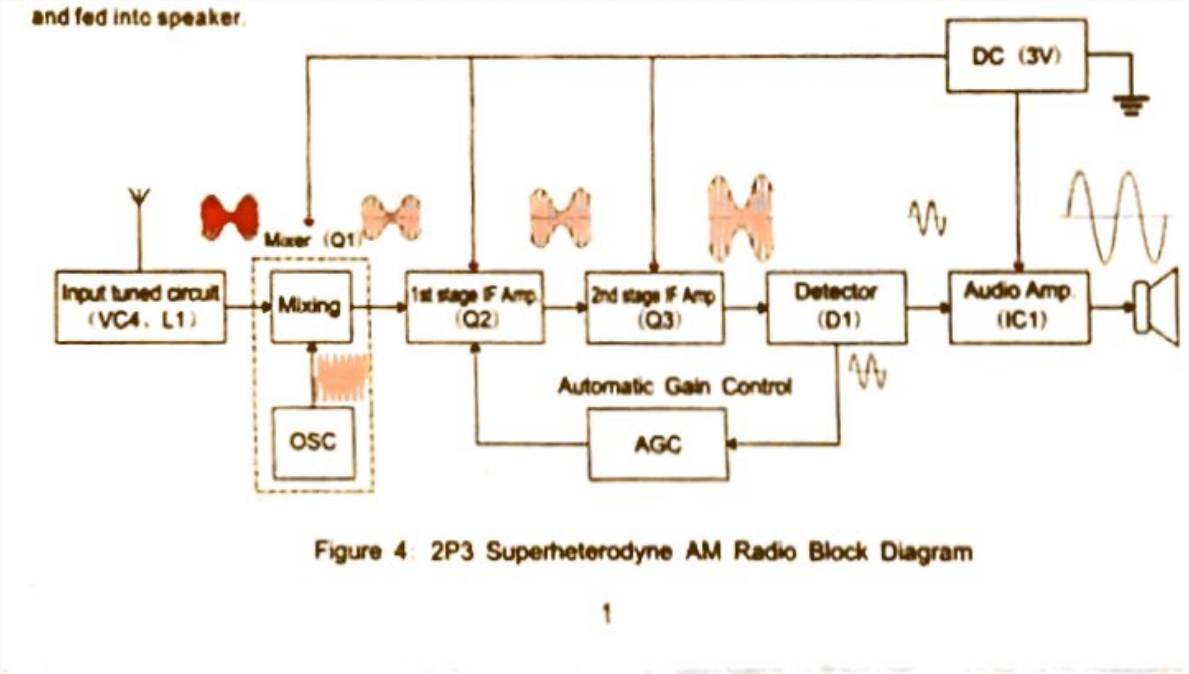


Figure 4: 2P3 Superheterodyne AM Radio Block Diagram

1

INTRODUCTION TO MIXING OR HETERODYNING

- Beat frequencies (heterodynes) occur at $f_r + f_{lo}$ and $f_r - f_{lo}$
- **Heterodyning** - make a signal oscillate at $f_r + f_{IF}$, then mix with f_{IF} and filter out the higher heterodyne
- The result: AM radio at f_{IF}, with modulations in tact
- The **detector** (diodes) grabs only the modulations



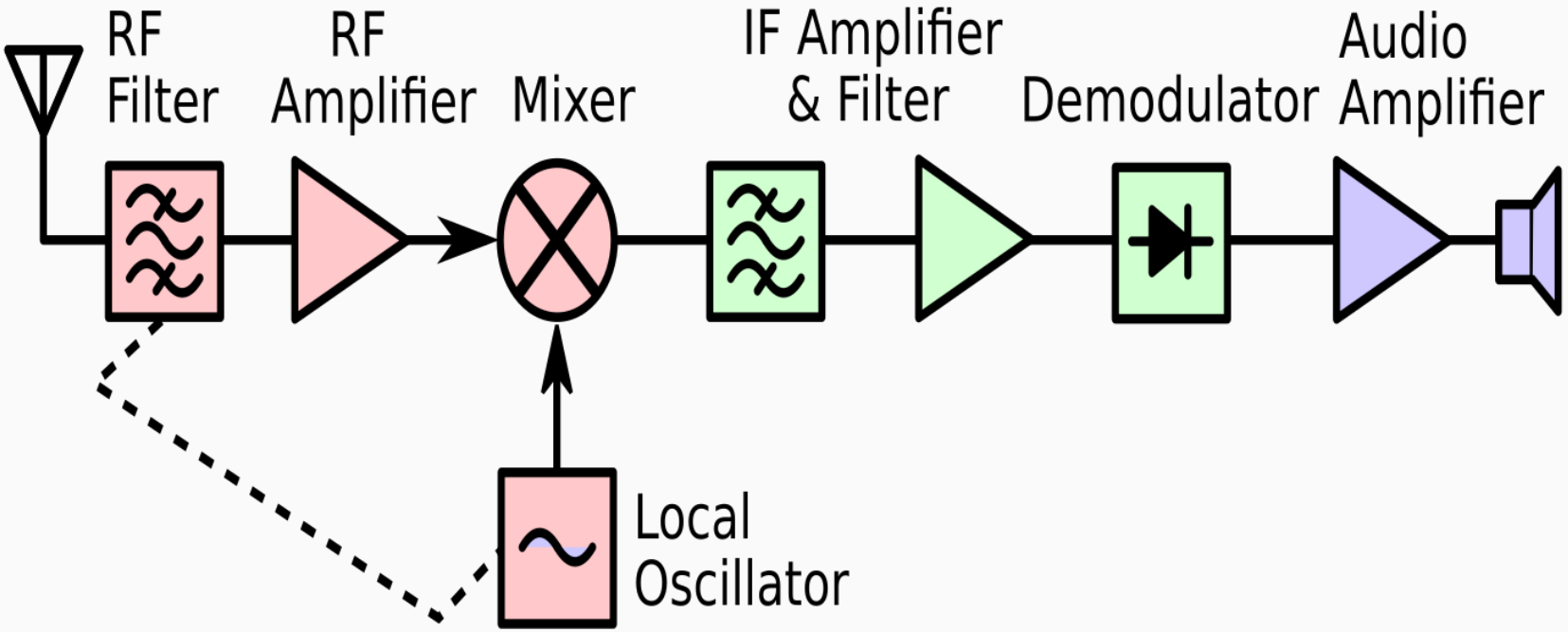


Figure 1: Source: Wikipedia. A superheterodyne AM receiver uses an intermediate frequency (IF) to capture the audio modulations.

INTRODUCTION TO TRANSISTORS

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

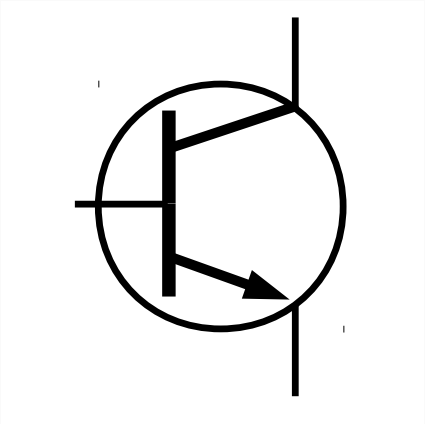


Figure 2: The schematic symbol for the transistor, including the *emitter*, *base*, and *collector*. Amplified (positive) current flows from the emitter to the collected when the base has a positive voltage.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

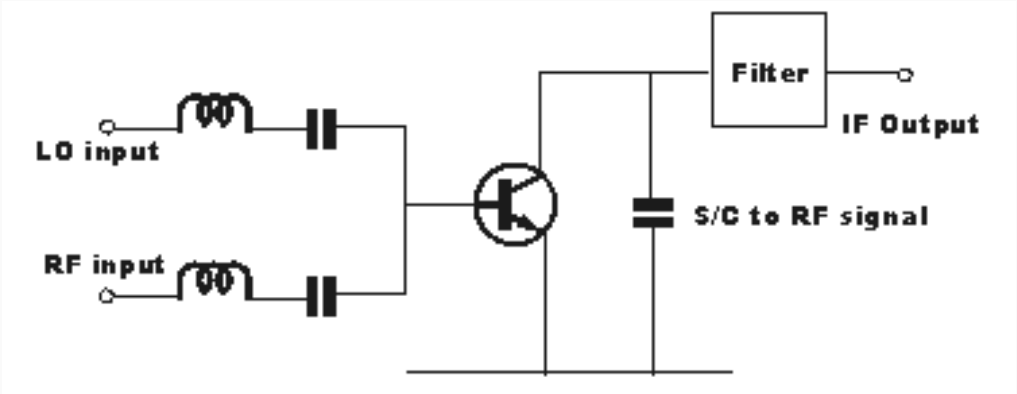


Figure 3: The bipolar-junction transistor mixer. A local oscillator is connected in parallel with the *base* of the bipolar transistor. Positive current flows from the emitter to the collector when *either* the oscillator oscillates or the radio antenna oscillates. The capacitor at right soaks up unwanted high frequencies.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

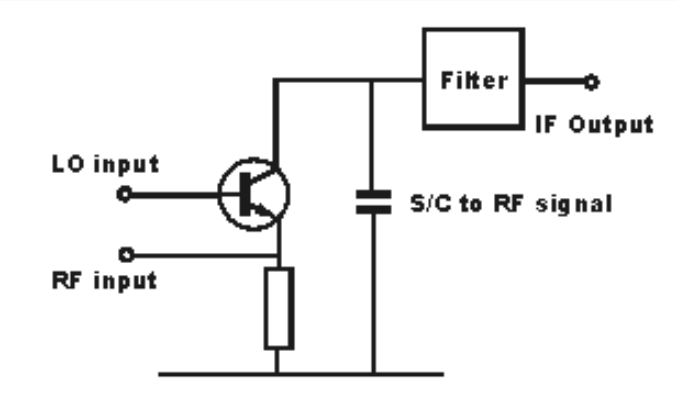


Figure 4: The bipolar-junction transistor mixer. In this example the radio frequency (RF) input is connected to the emitter and the LO is connected to the base. One more level of complexity and we have a circuit close to that of the 2P3...

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

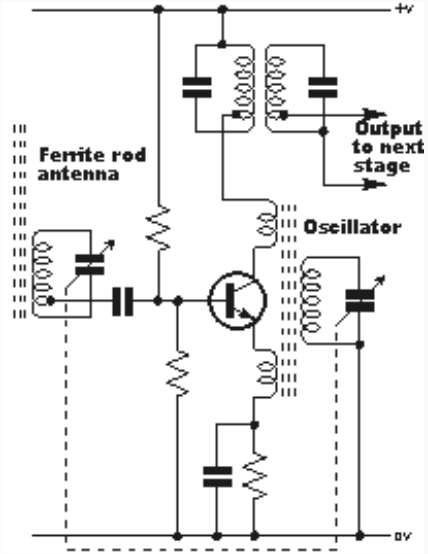


Figure 5: In this final example, the LO and the mixer are combined into one circuit.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

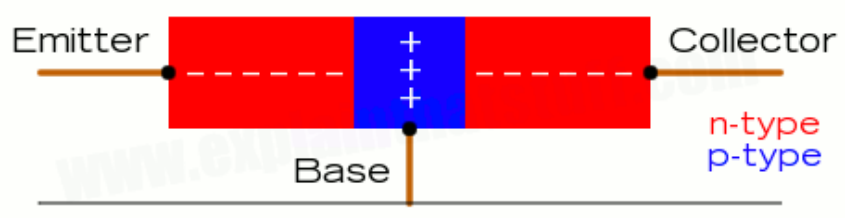


Figure 6: A bipolar junction transistor, off-state.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

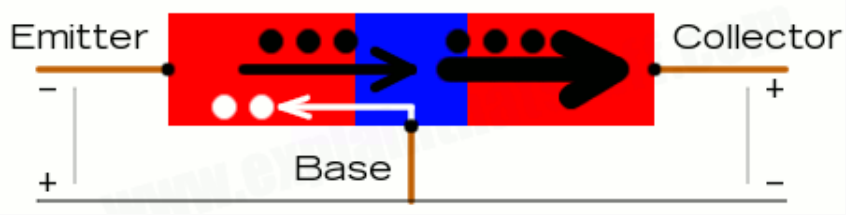


Figure 7: A bipolar junction transistor, on-state. Notice two things a) amplification and b) the switching effect.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

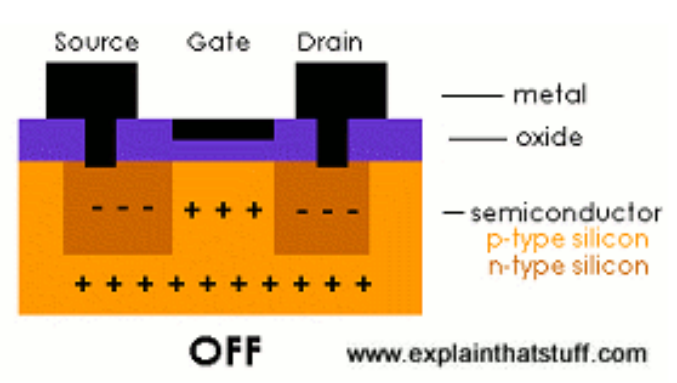


Figure 8: A metal oxide field effect transistor, off-state.

- How does a mixer use the transistor?
- How does a transistor work?
- We will use this as an opportunity to learn how transistors may be used to form digital circuits.

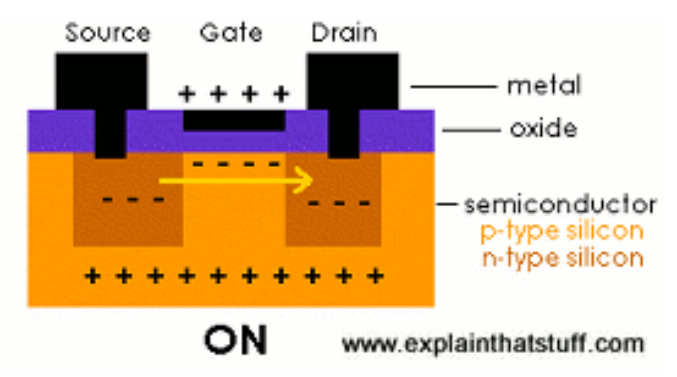


Figure 9: A metal oxide field effect transistor, on-state. The electric field created by the gate polarizes a channel between the source and drain, allowing current to flow.

THE 2P3 SUPERHETERODYNE AM RADIO RECEIVER

THE 2P3 SUPERHETERODYNE AM RADIO RECEIVER

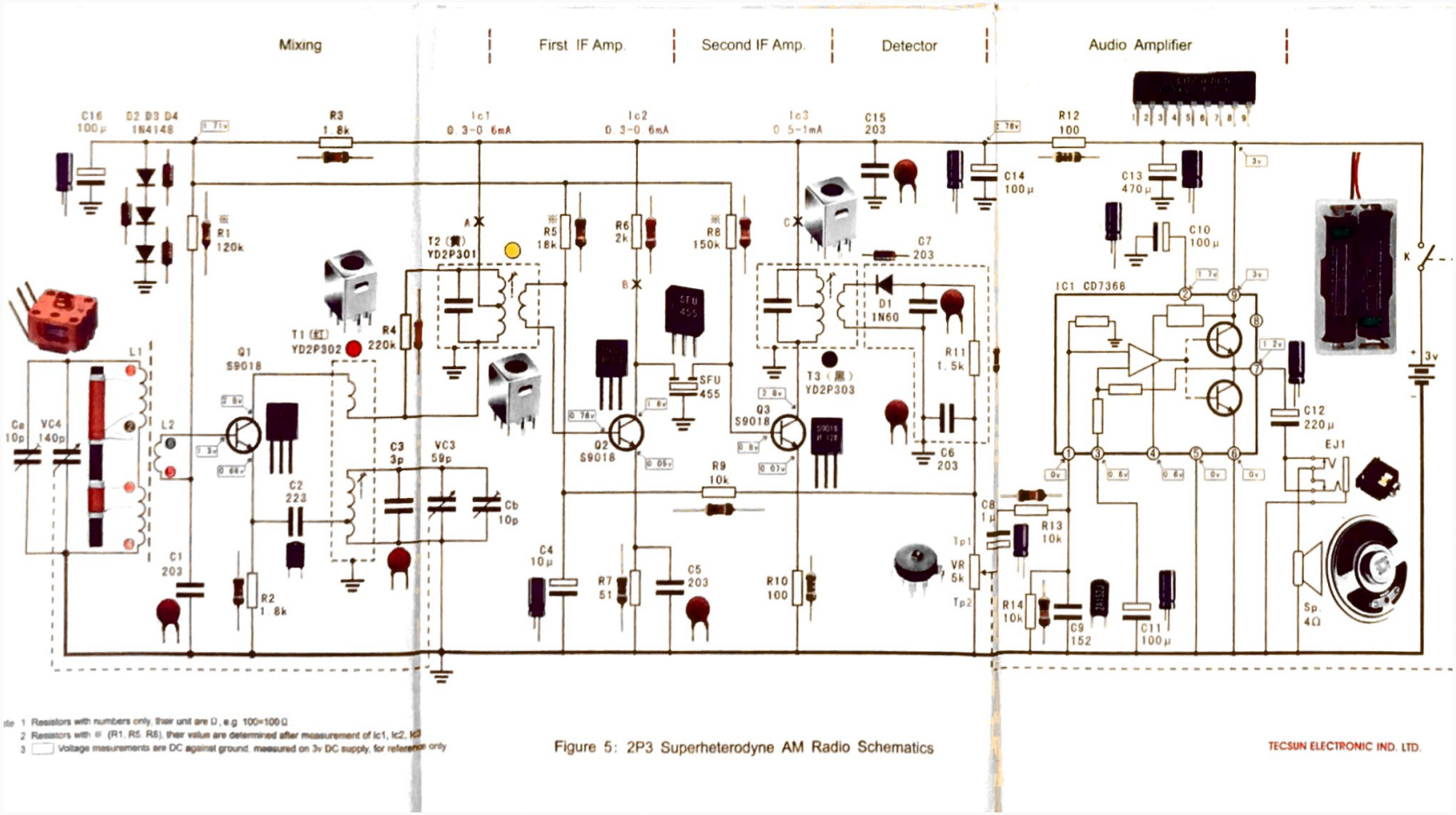


Figure 10: Where are the transistors in this AM transistor superhet? What roles do they play in each case?

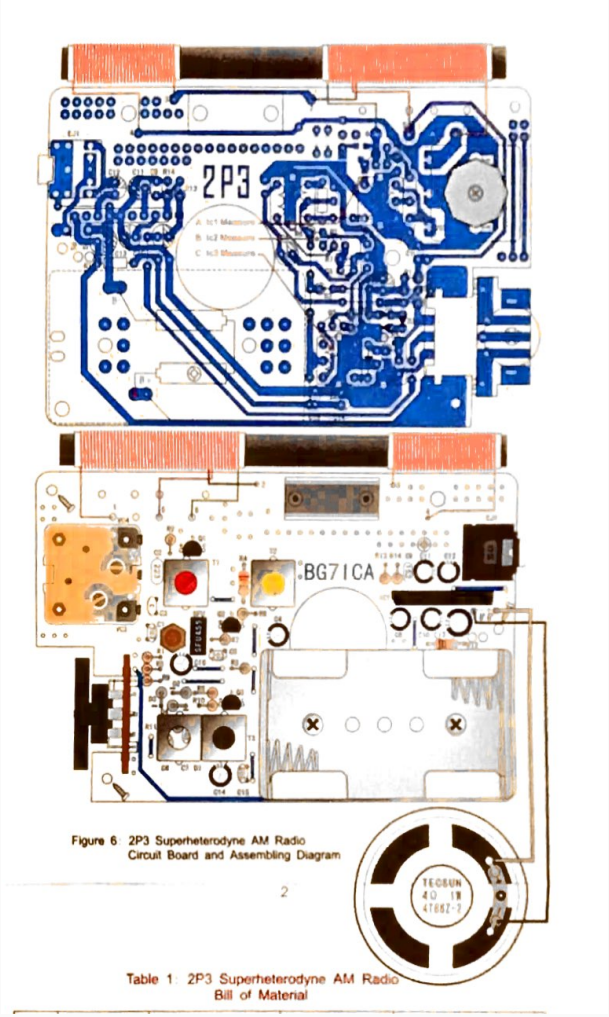


Figure 11: Through-hole style circuit board.

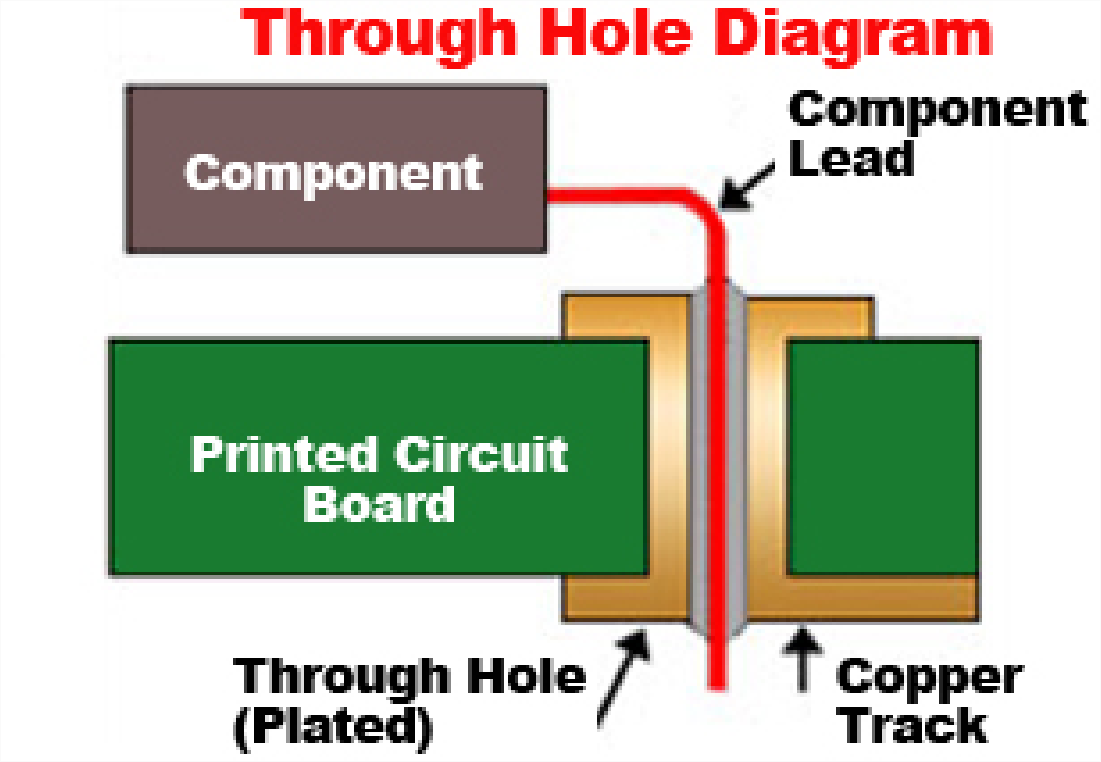


Figure 12: Through-hole style circuit board. By heating the copper (or other metal) track and the component lead, we may allow *solder* to flow onto the heated areas, binding them together in a conductive fashion.

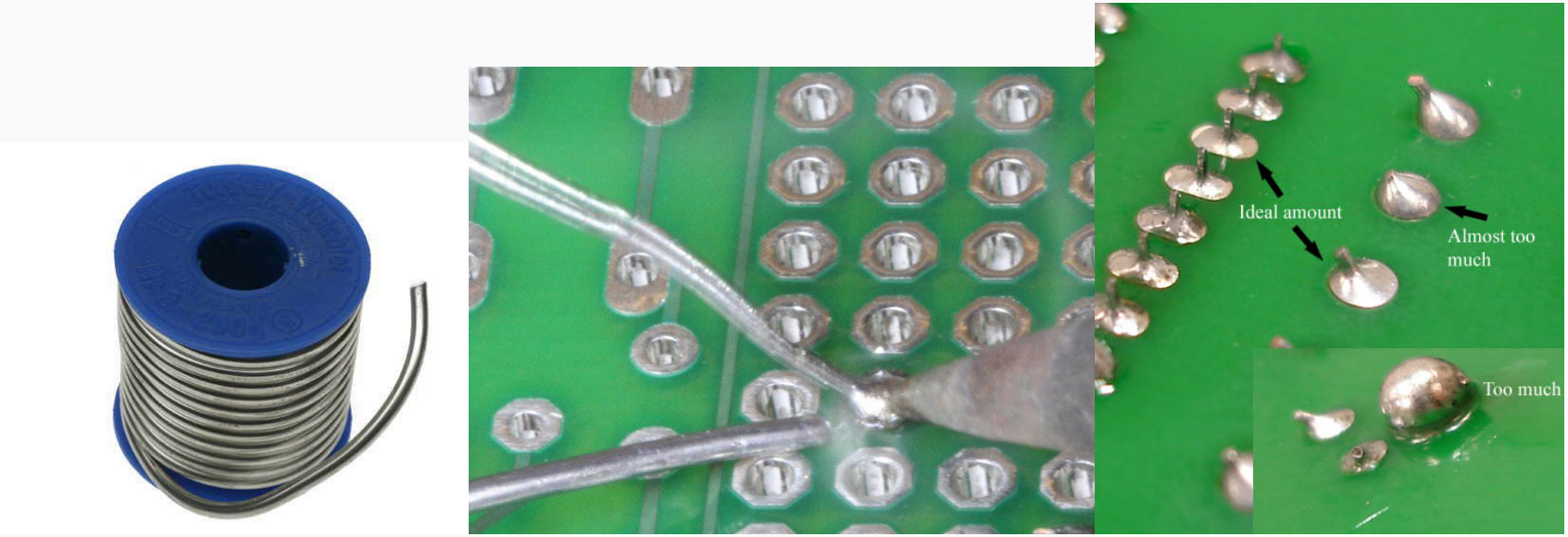


Figure 13: (Left) Solder, used to bind components to board. (Middle) Example of soldering iron causing solder to flow onto the heated hole. (Right) Exampls of correct and incorrect soldering.

Figure 14: The digital voltmeter (DVM) has three main functions: measuring voltage (voltmeter), measuring current (ammeter), and measuring conduction (the beep).

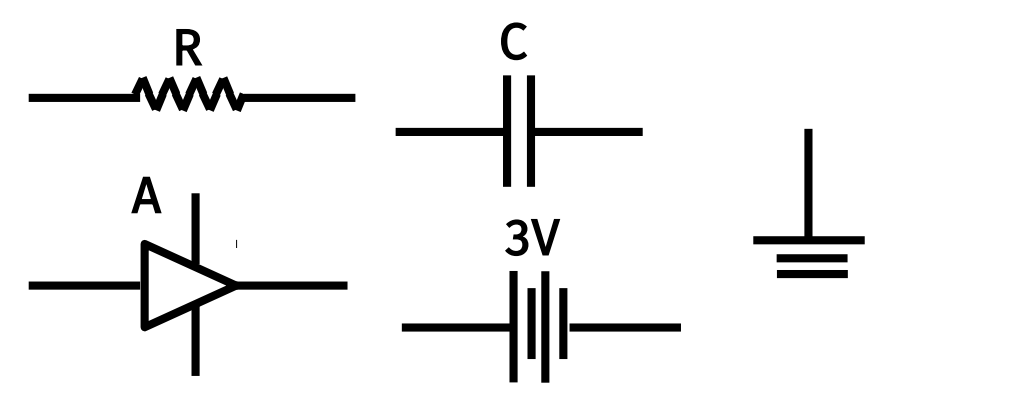


Figure 15: Other common components we will encounter in the 2P3 design.

Components:

- Resistors (resistance, R, color stripes) and capacitors (capacitance, C, numerical code)
- Amplifiers (IC1 in 2P3, made from transistors and amplifies voltages)
- Battery, voltage source (2P3 requires 3V from two series AA batteries)
- Ground (located in certain places on the circuit board, usually tied to negative battery terminal)

GO BUILD STUFF.

A 2P3 walkthrough: `https://youtu.be/suDvdfjmNjk`

CONCLUSION

Unit 1.2 summary - Build a radio from a pile of parts...go!

1. Introduction to *mixing* or heterodyning
   - The **transistor** plays a dual role
   - **Transistors** $\rightarrow$ forthcoming units on logic gates
2. The superheterodyne (superhet) radio receiver
3. Through-hole soldering 101
4. The DVM (digital voltmeter)
5. **Build.** $\rightarrow$ Bonus point for the first team