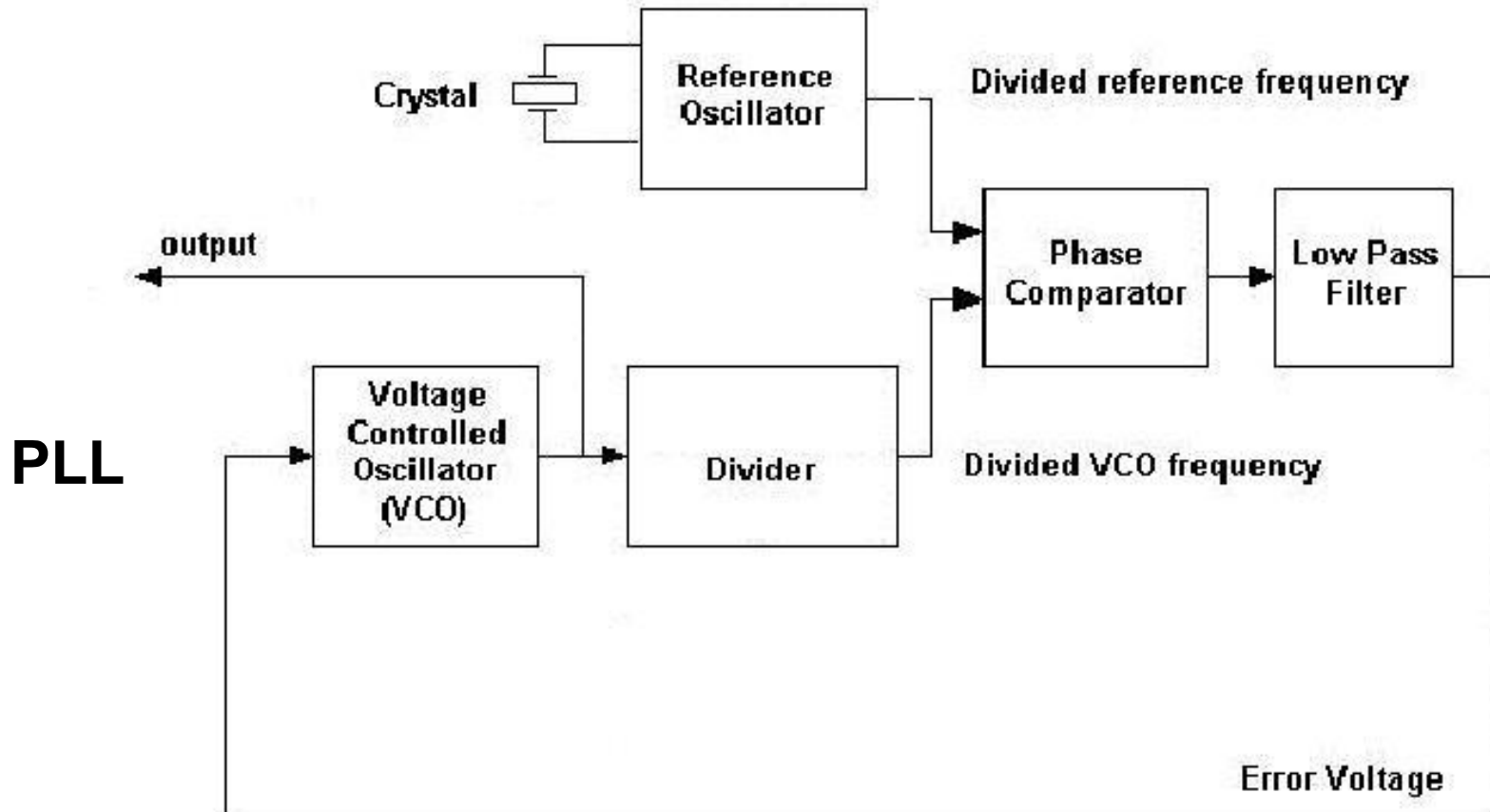# *The New England Radio Discussion Society electronics course (Phase 4, cont'd)*
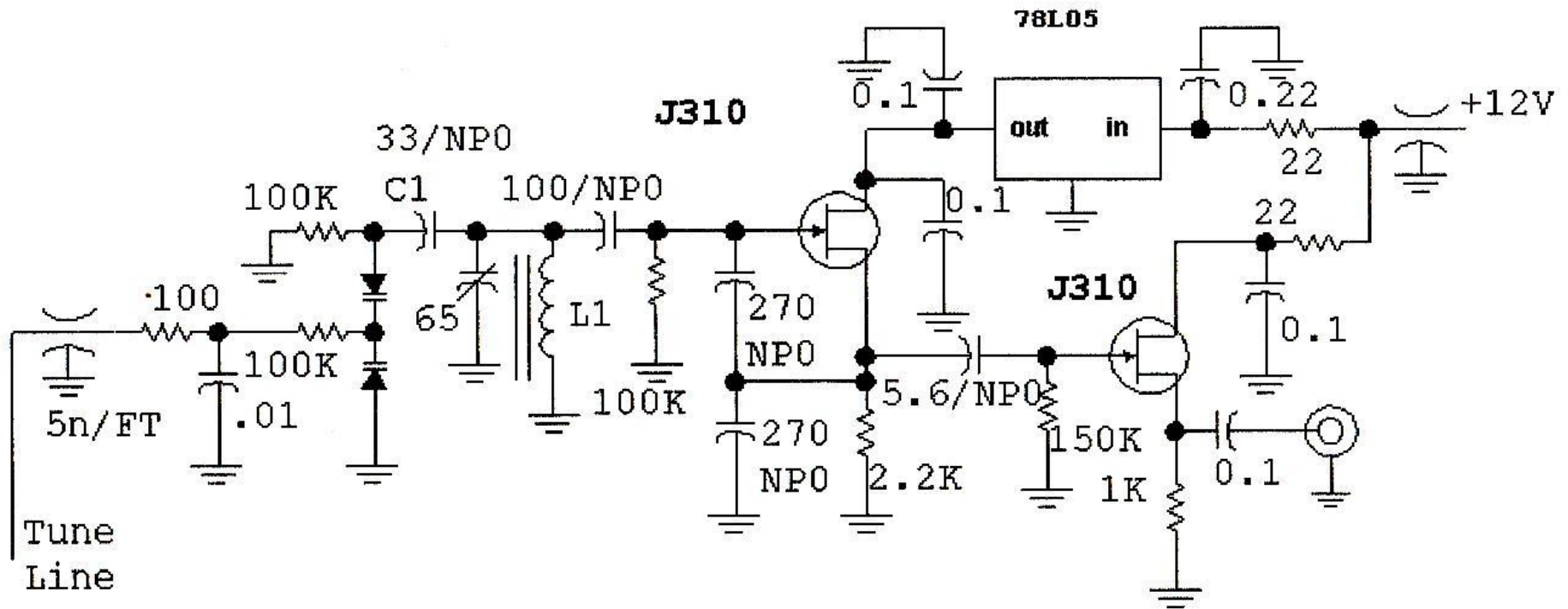
Introduction to receivers

AI2Q – April 2017
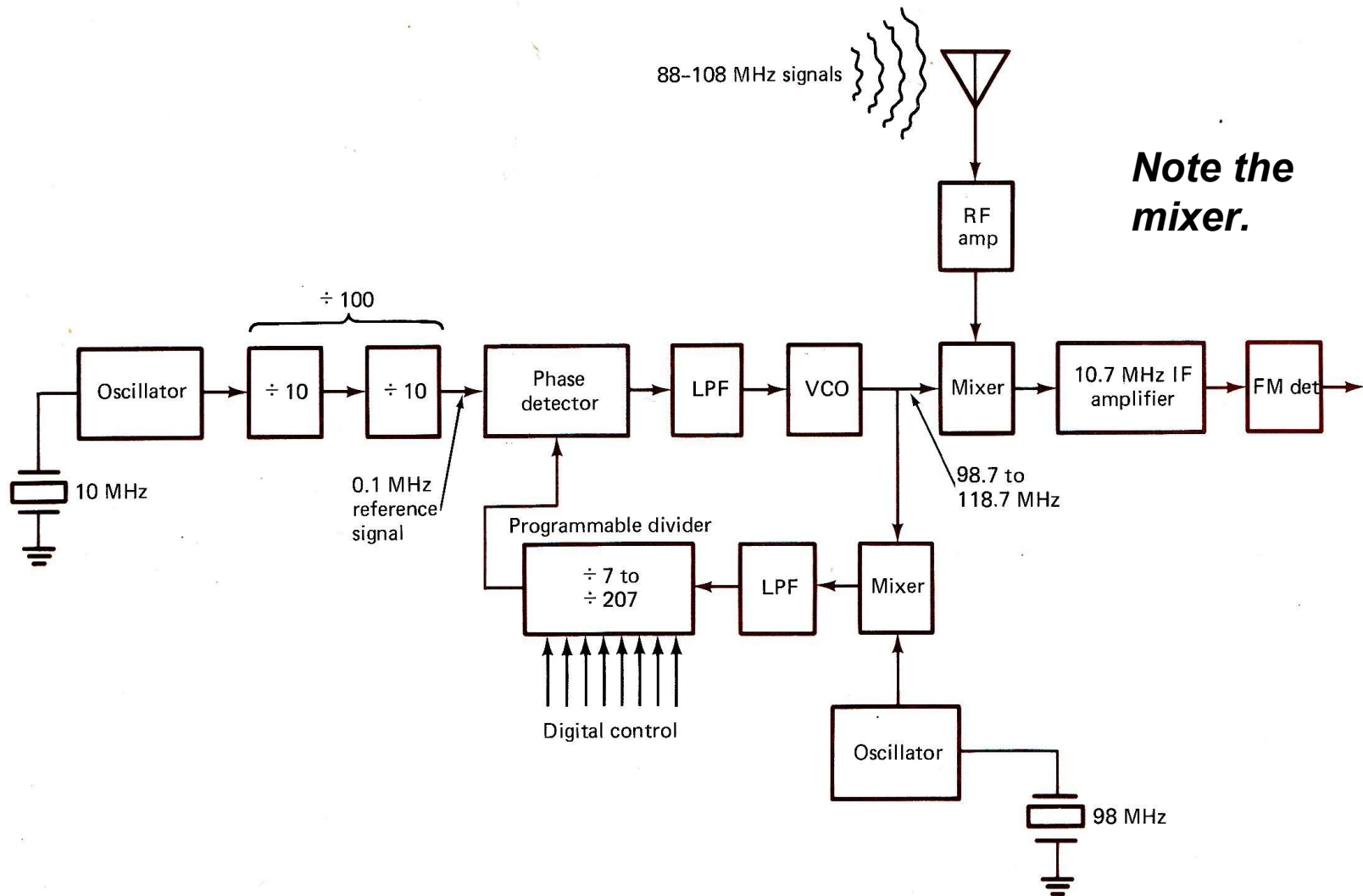
REVIEW: a VFO, phase-locked loop (PLL), or direct digital synthesizer (DDS), can be used to set the frequency of a receiver or transmitter.

Crystal — Reference Oscillator — Divided reference frequency

output

Phase Comparator — Low Pass Filter

PLL

Voltage Controlled Oscillator (VCO) — Divider — Divided VCO frequency

Error Voltage

REVIEW: a typical circuit for a VCO and buffer, using JFET devices.

This block diagram shows the architecture for a digitally tuned FM broadcast band radio.


88–108 MHz signals

Note the mixer.

÷ 100

Oscillator → ÷ 10 → ÷ 10 → Phase detector → LPF → VCO → Mixer → 10.7 MHz IF amplifier → FM det

10 MHz

0.1 MHz reference signal

Programmable divider

÷ 7 to ÷ 207

LPF ← Mixer

Digital control

RF amp

98.7 to 118.7 MHz

Oscillator

98 MHz

Let's look a bit more closely at receivers.

Here's a schematic diagram of the simplest AM radio receiver. The diode rectifies the modulated RF signal and produces audio.

Radio signal

Antenna

Detector

Headphones

Earth ground
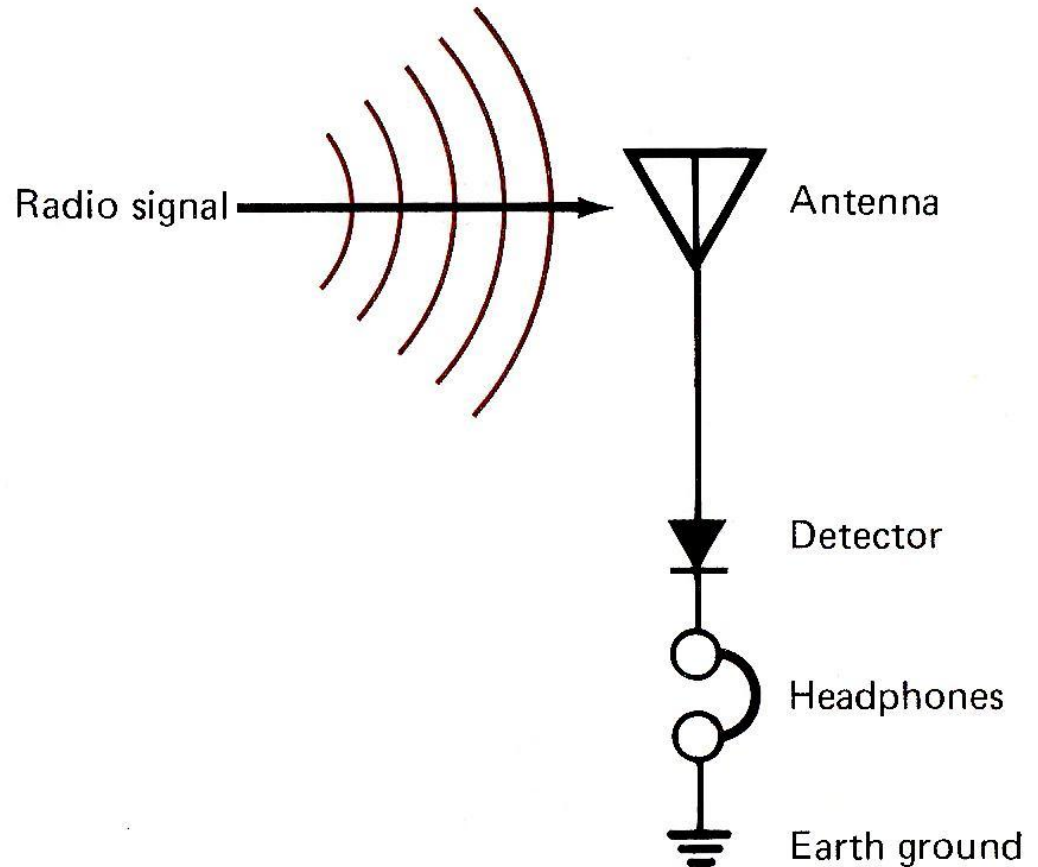
The diode detector (previous slide) "detects" amplitude modulation by rectifying the AM signal peaks.

Diode detectors sometimes use "filter" capacitors to smooth the resulting varying "DC."
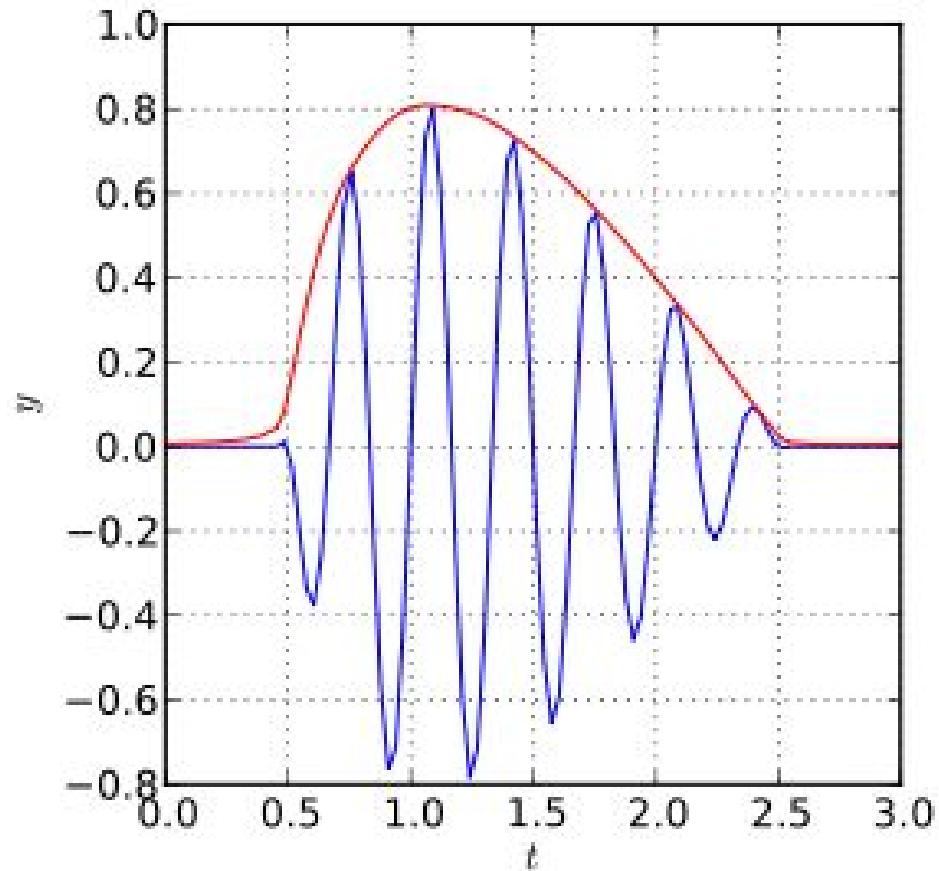
The crystal radio is the simplest type of detector. Because there's no amplifier stage, the detected audio is very clean and crisp.

Note the "filter" capacitor at the output of the 1N34A germanium diode rectifier.
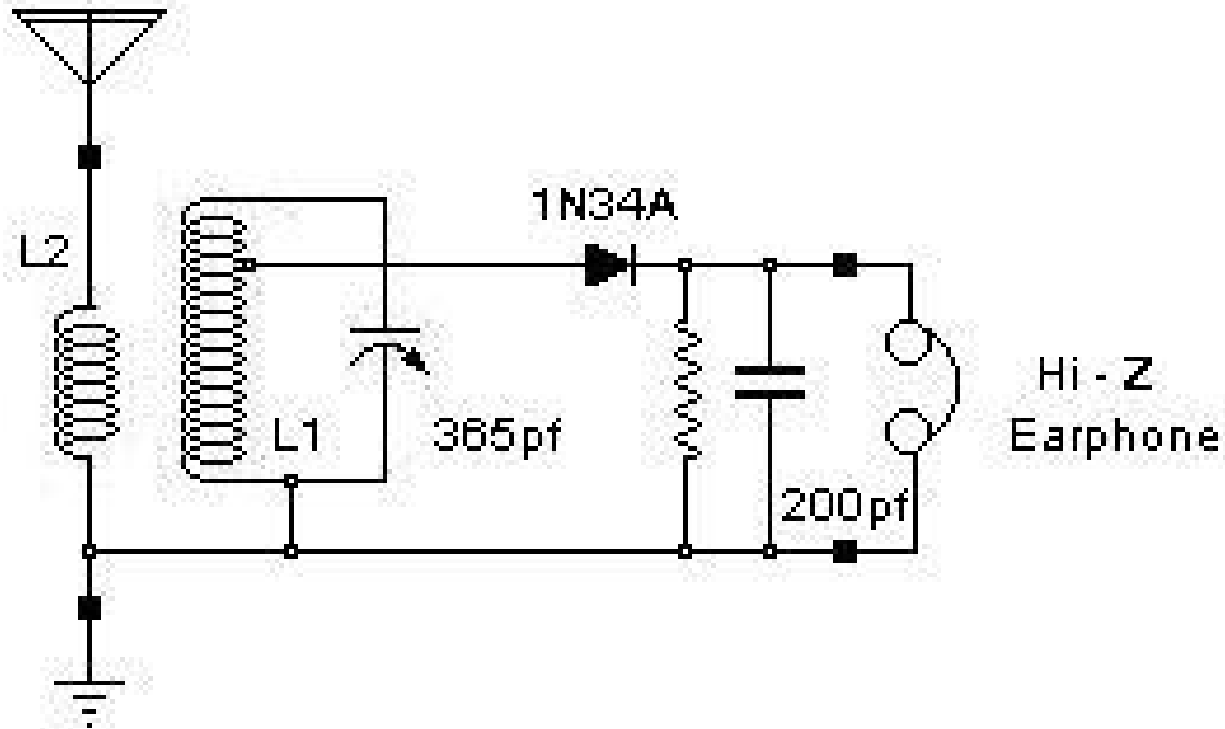
Adding a resonant LC circuit to the "front-end" improves a receiver's *selectivity*. Ganged audio amplifiers provide gain in this simple receiver architecture.

Tuned circuit — Detector — Audio amplifier — Audio amplifier
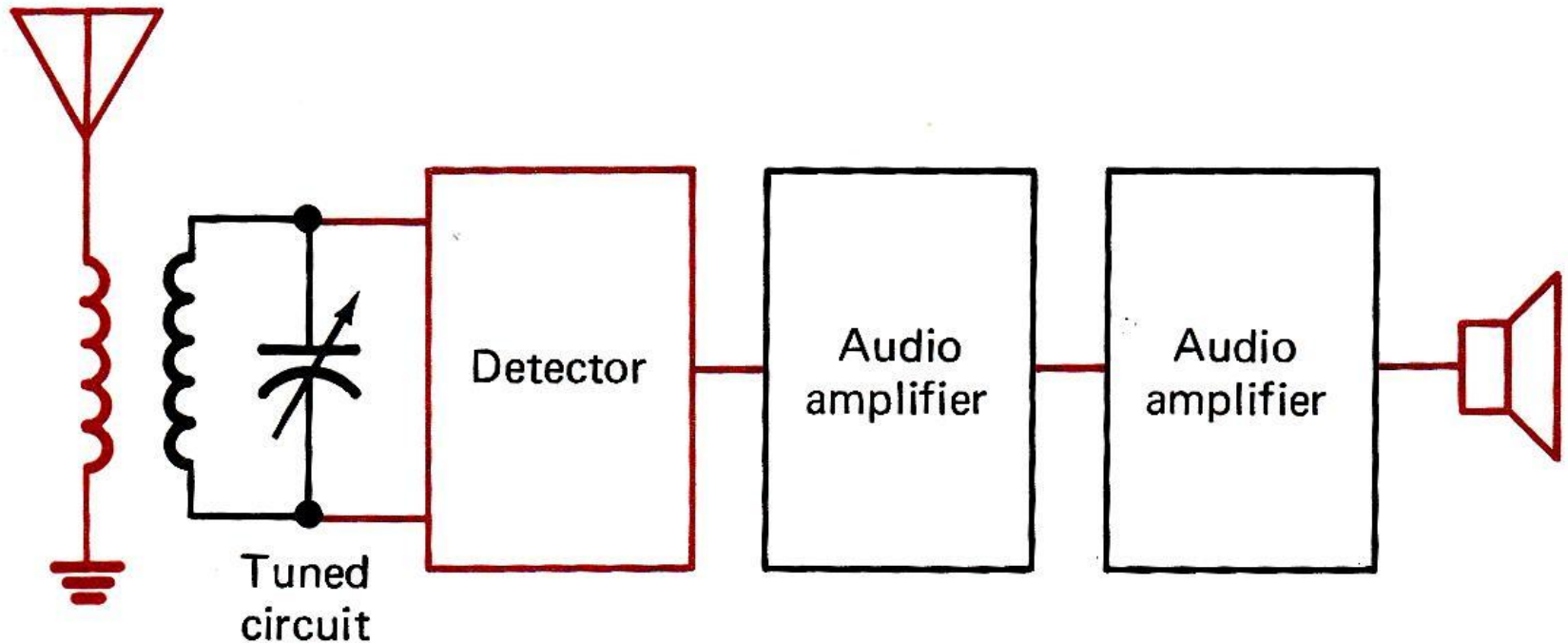
More resonant tuned LC circuits can improve a receiver's selectivity. The response curves become sharper (lower bandwidth) and can reject unwanted frequencies.
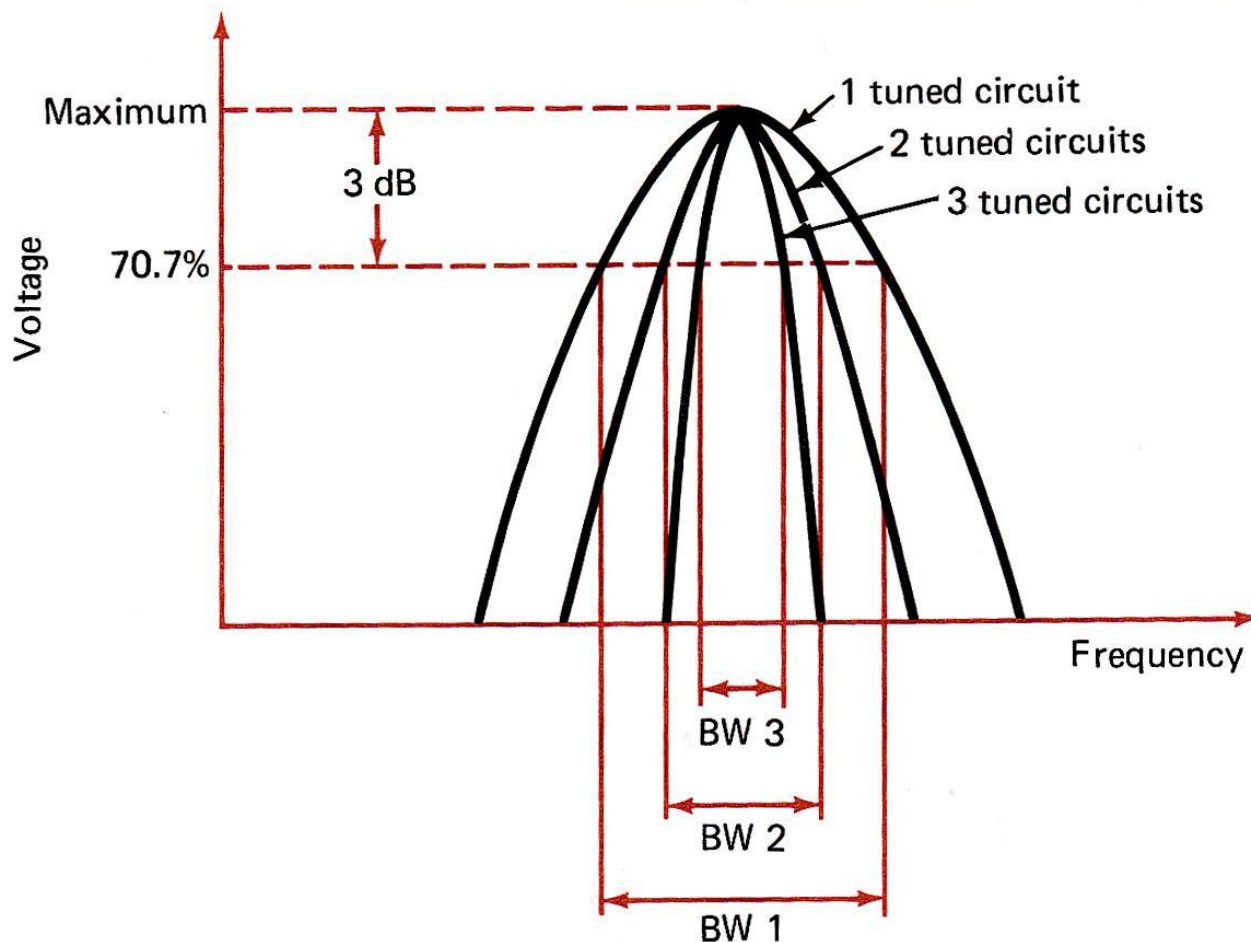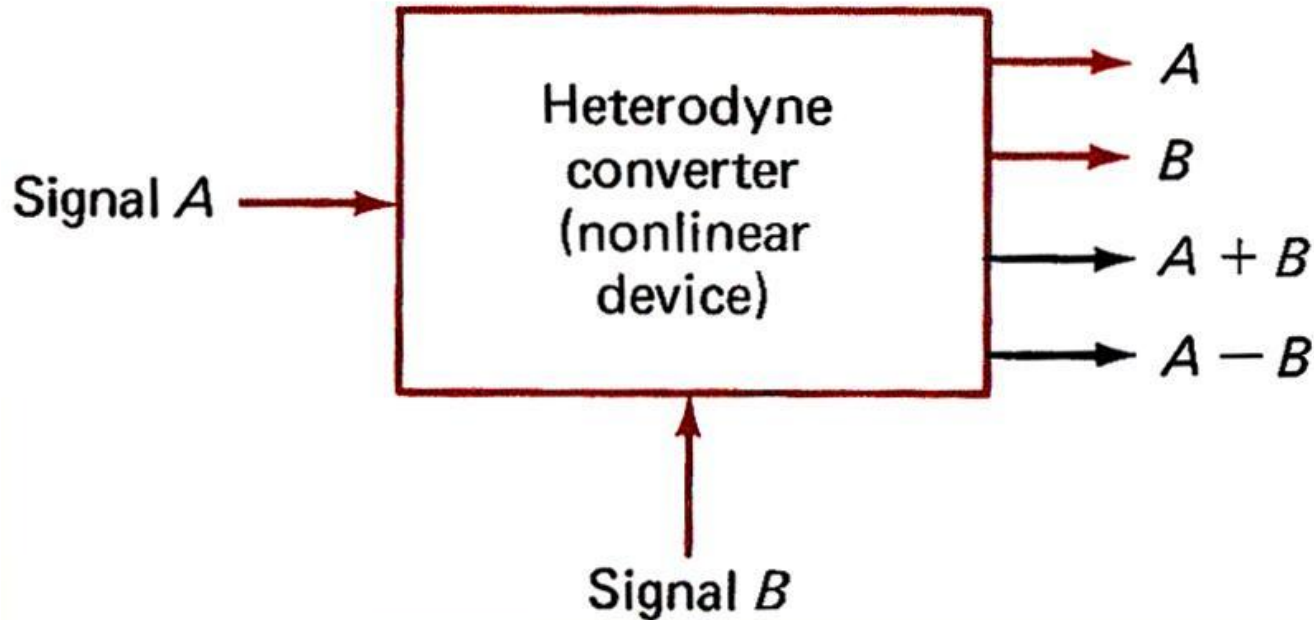
This diagram shows a *tuned radio frequency* receiver, otherwise known as a *TRF*. The TRF architecture usually requires that all tuned circuits track each other, which may be difficult to achieve. Also, the bandwidth of the LC circuits will vary with frequency.

Gang tuning
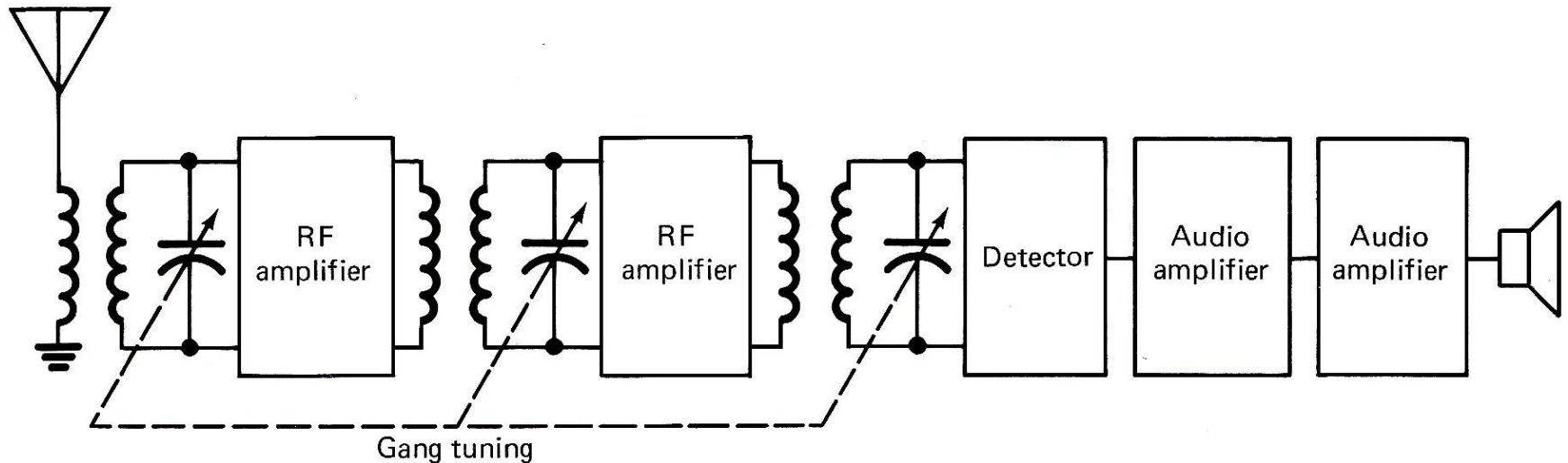
How can these disadvantages be overcome? == >>
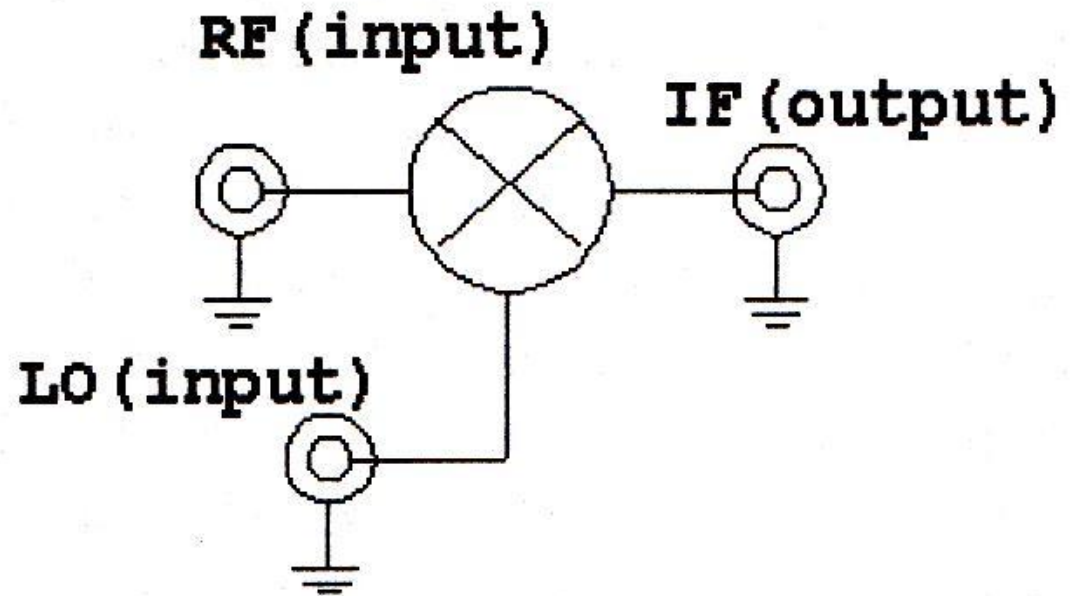
Yes!   Enter the *mixer.*

Any non-linear device can work as a mixer. When two different frequencies are applied, new frequencies are produced. The output contains the original two frequencies as well as the new sum and the difference frequencies. This is called *heterodyning*.

A mixer is often shown on a diagram as a circle with an X across it.

Mixers are also sometimes called *converters*.

This particular diagram also shows the representation of some input and output coaxial RF jacks.

RF (input)

IF (output)

LO (input)

A mixer can accept a signal from an antenna as well as from a local oscillator. The LO can be a crystal-controlled oscillator, a VFO, a PLL, or a DDS. An *intermediate frequency*, or IF, is generated. The other three outputs of the mixer are rejected by tuned circuits in the IF amplifier.
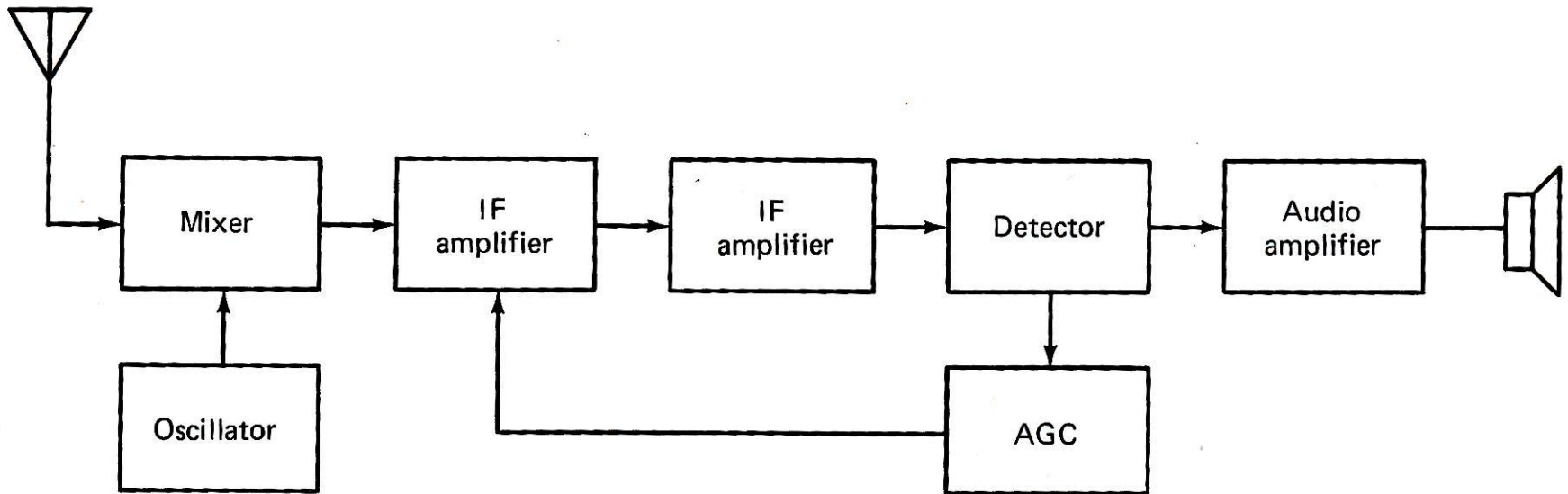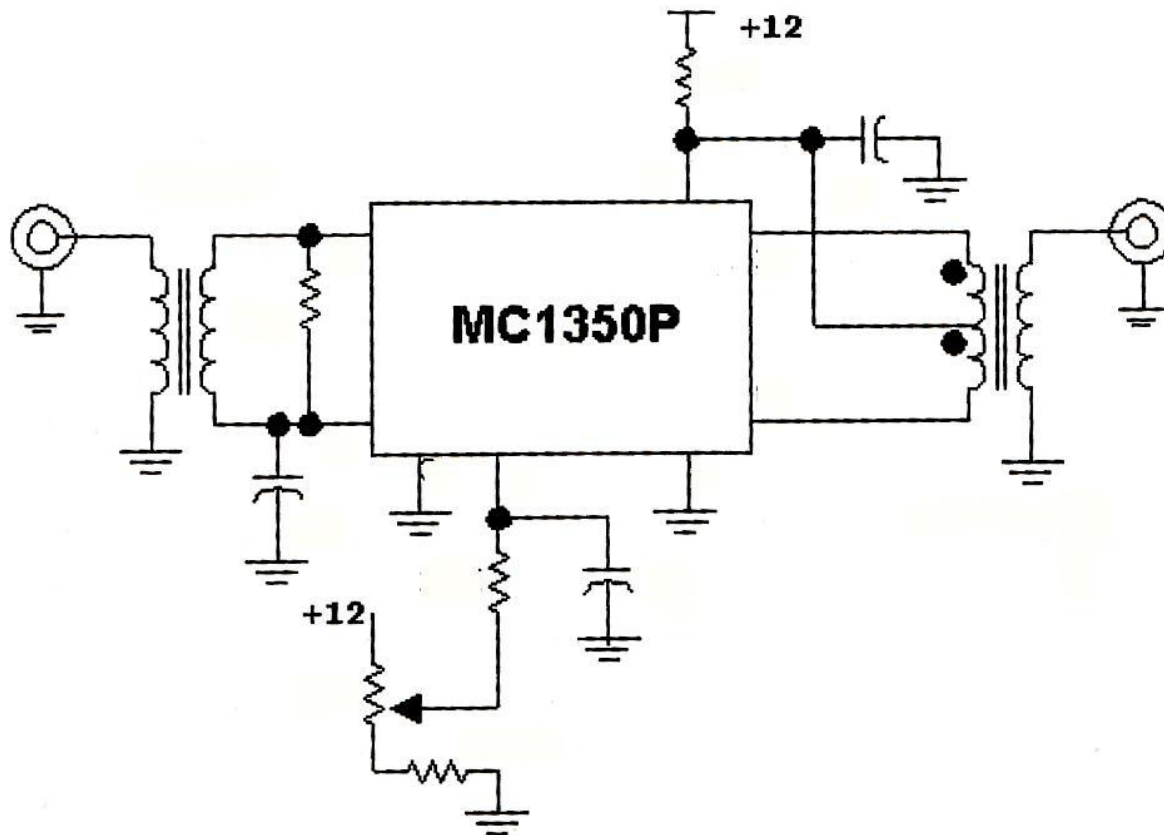
**Mixers can be configured with passive devices, such as diodes. Diodes are non-linear devices.**
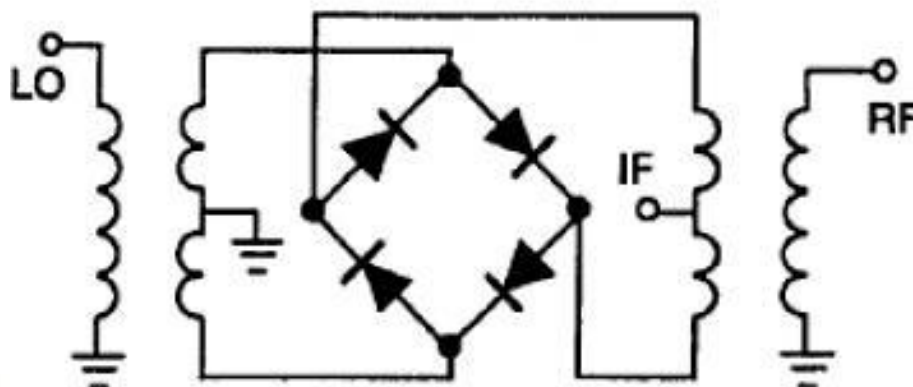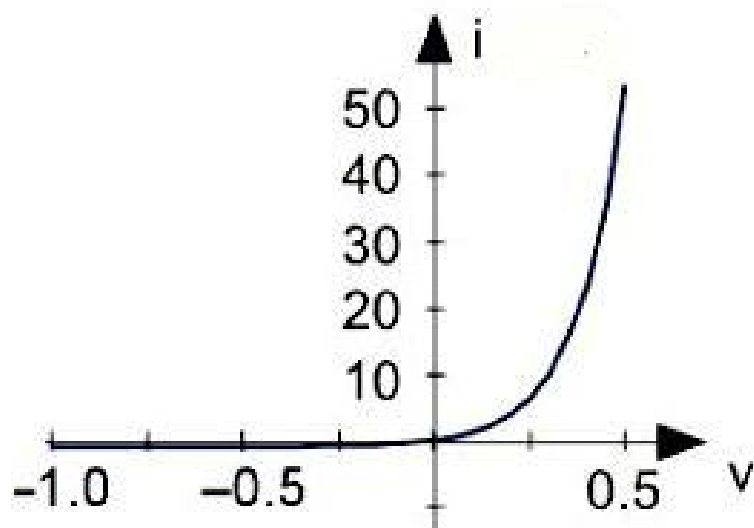
Here a single NPN BJT is used as a mixer. The transistor is biased into its nonlinearity region on its transfer curve.
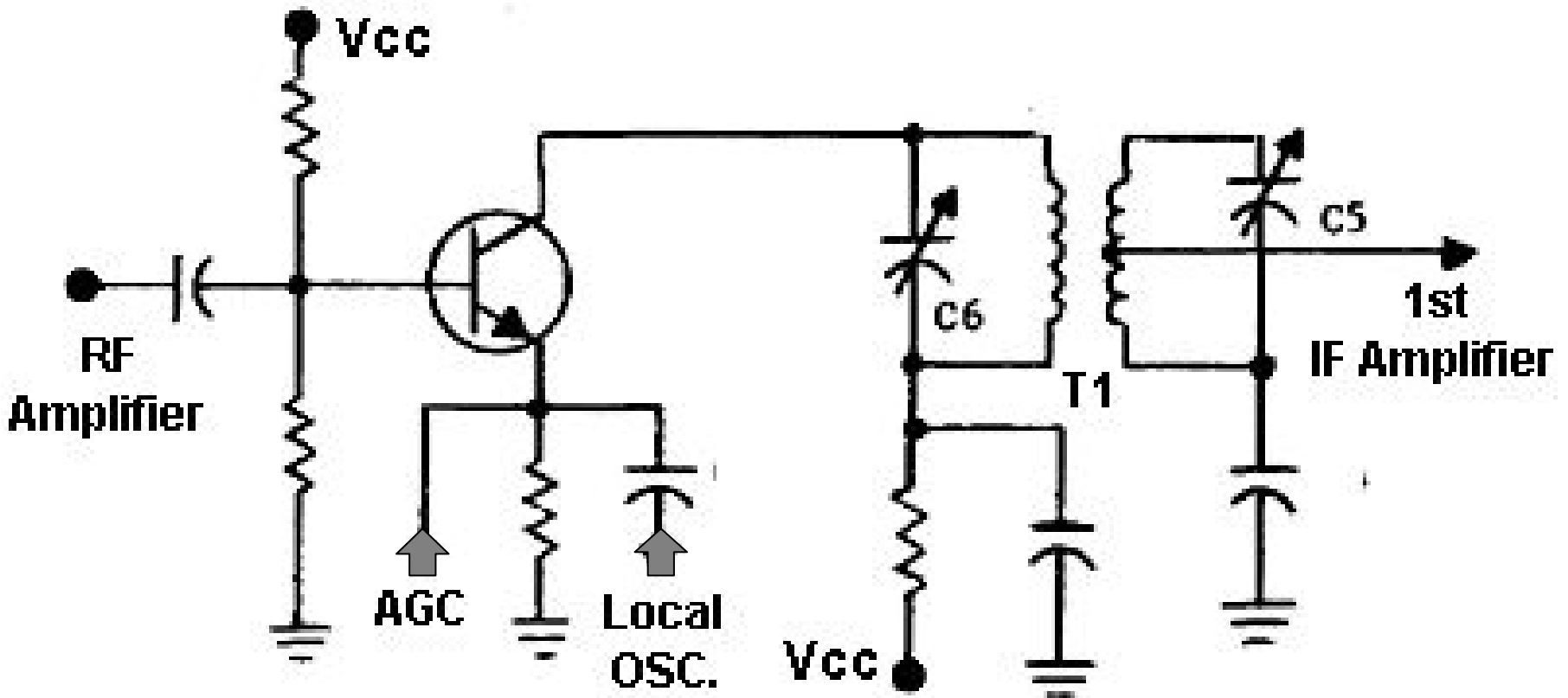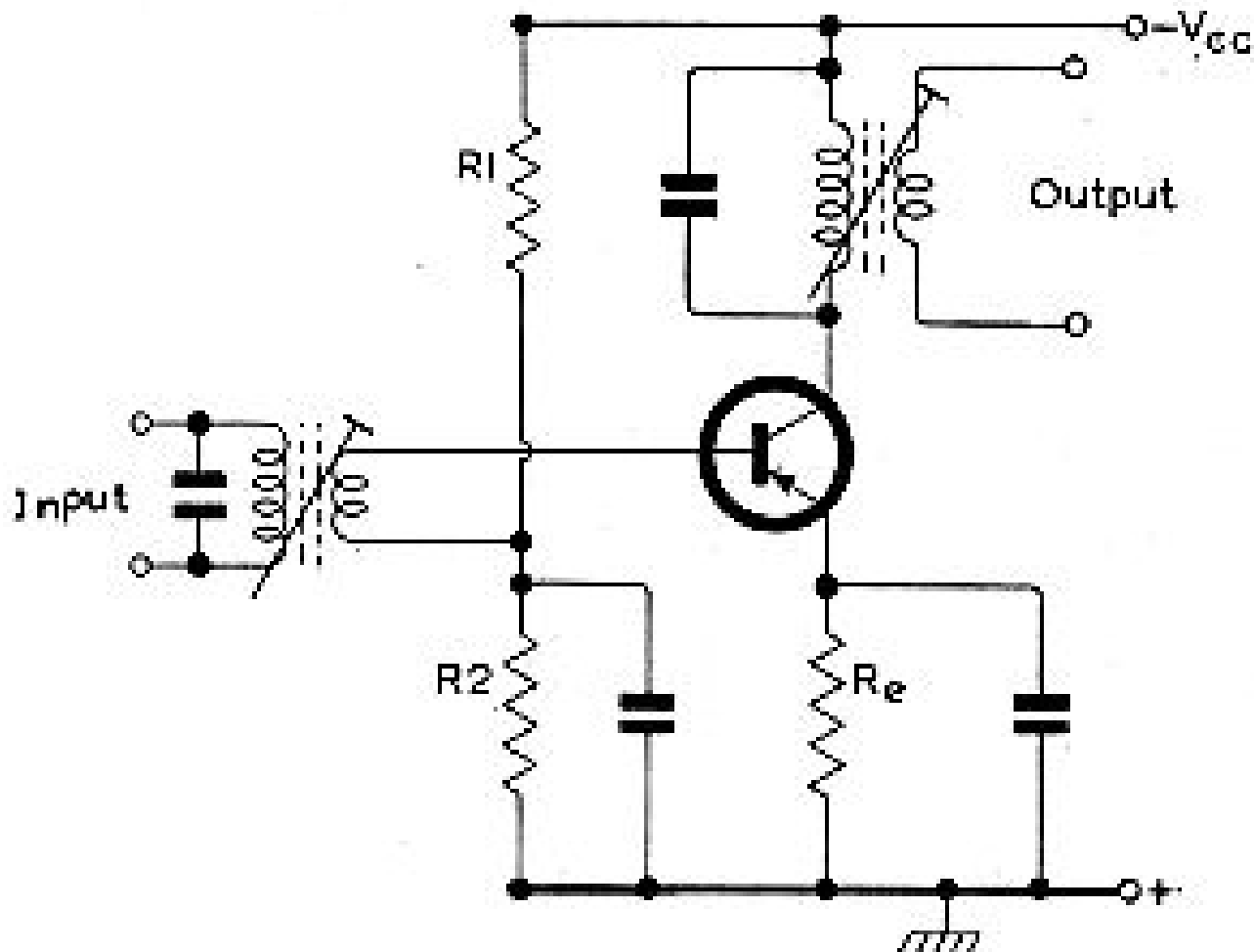
IF amplifiers can use discrete devices (previous slide) or integrated circuits. The *Motorola MC1350P* chip is a popular IC for IF amplifier applications.
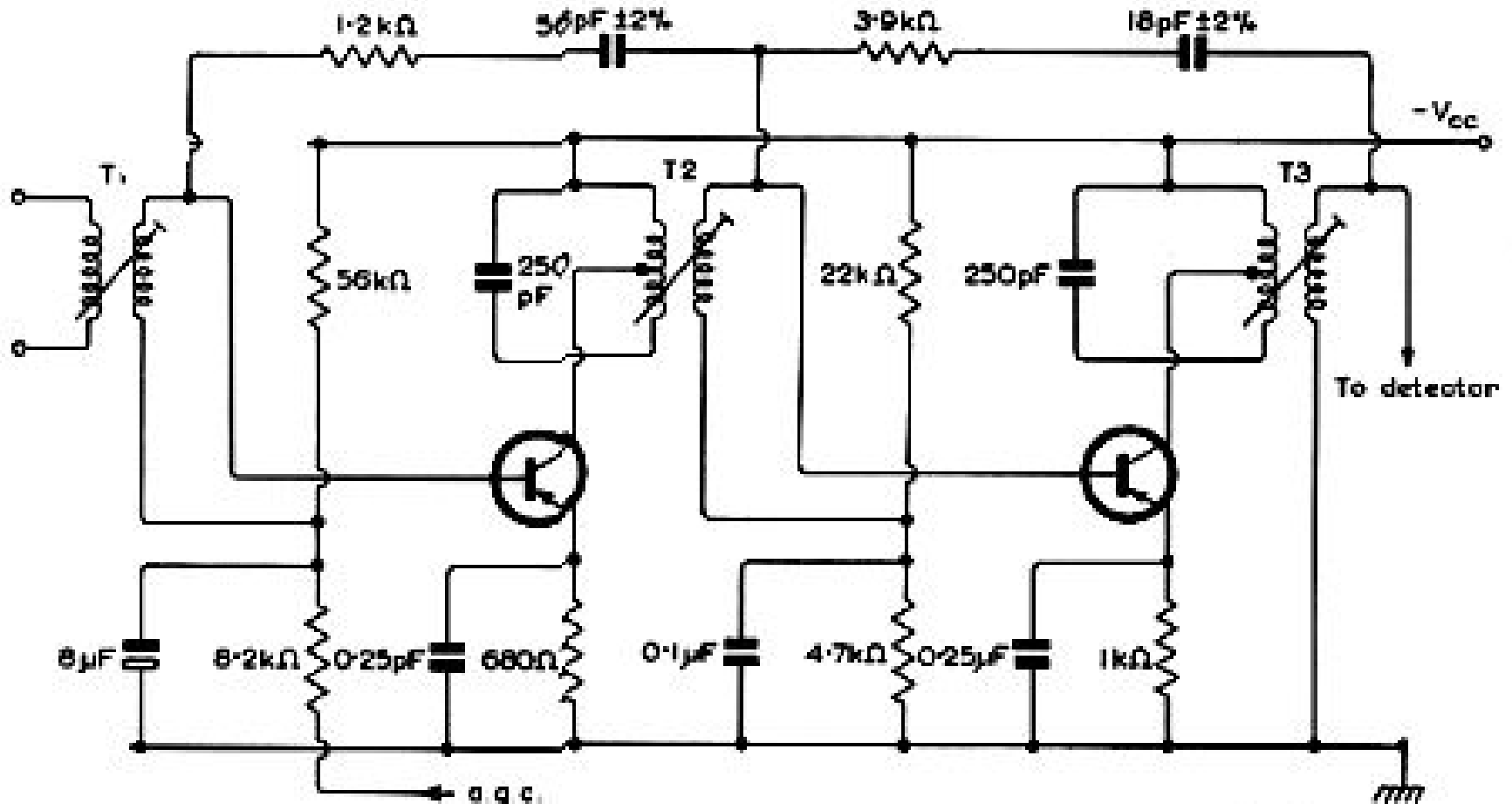
Here's a more elaborate IF amplifier "strip" using one MC1350P chip and a MC1330AP video detector chip.
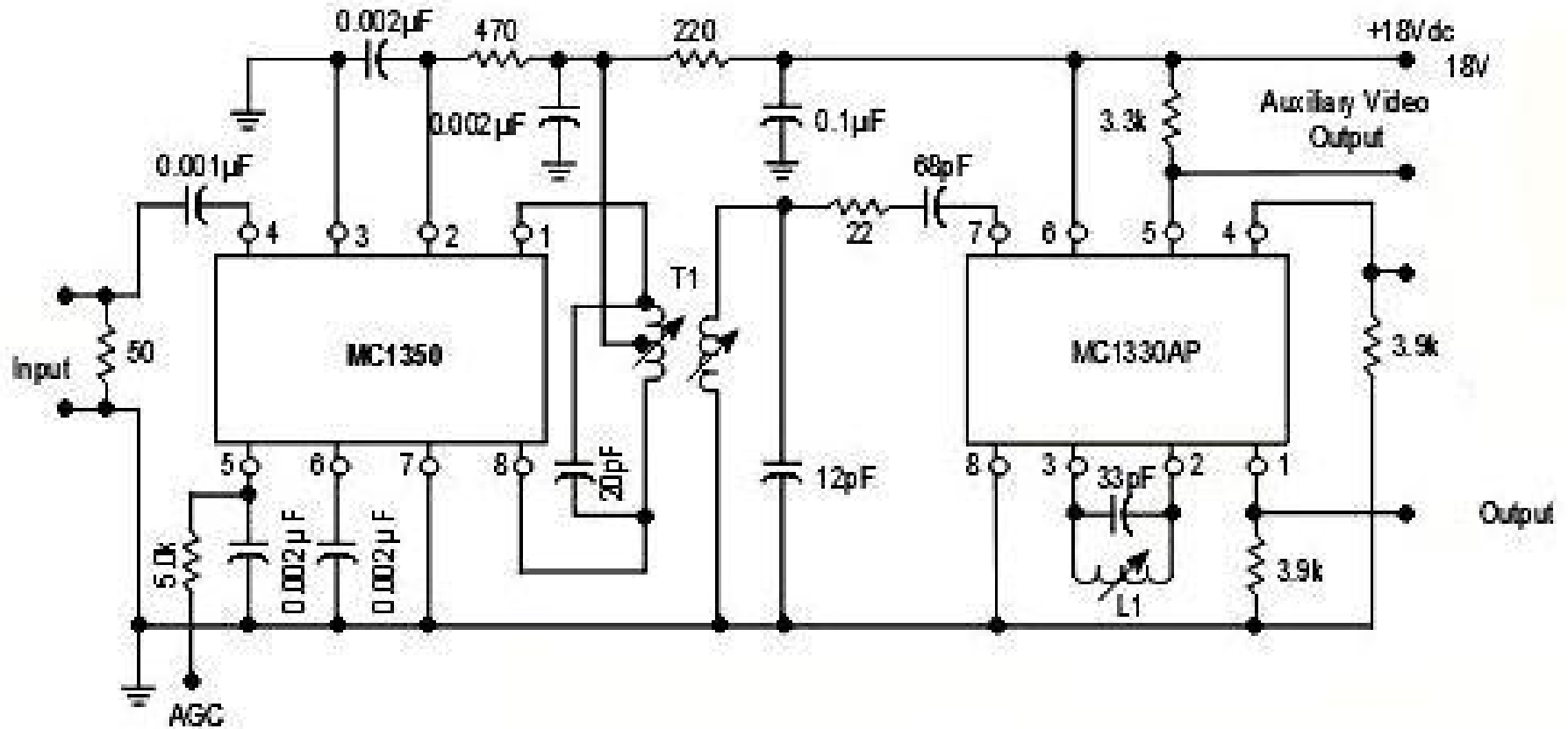
Here a single PNP BJT is used as an IF amplifier stage. Note the symbols for adjustable IF transformers.

This IF amplifier strip uses a pair of BJTs to achieve high gain and selectivity.

This IF stage is based on a pentode vacuum tube. IF transformers T4 and T5 are adjustable to set, or *peak*, the IF stage's exact frequency where gain is optimum. Variable capacitors C8, C9, C10, and C11 are used in this design.
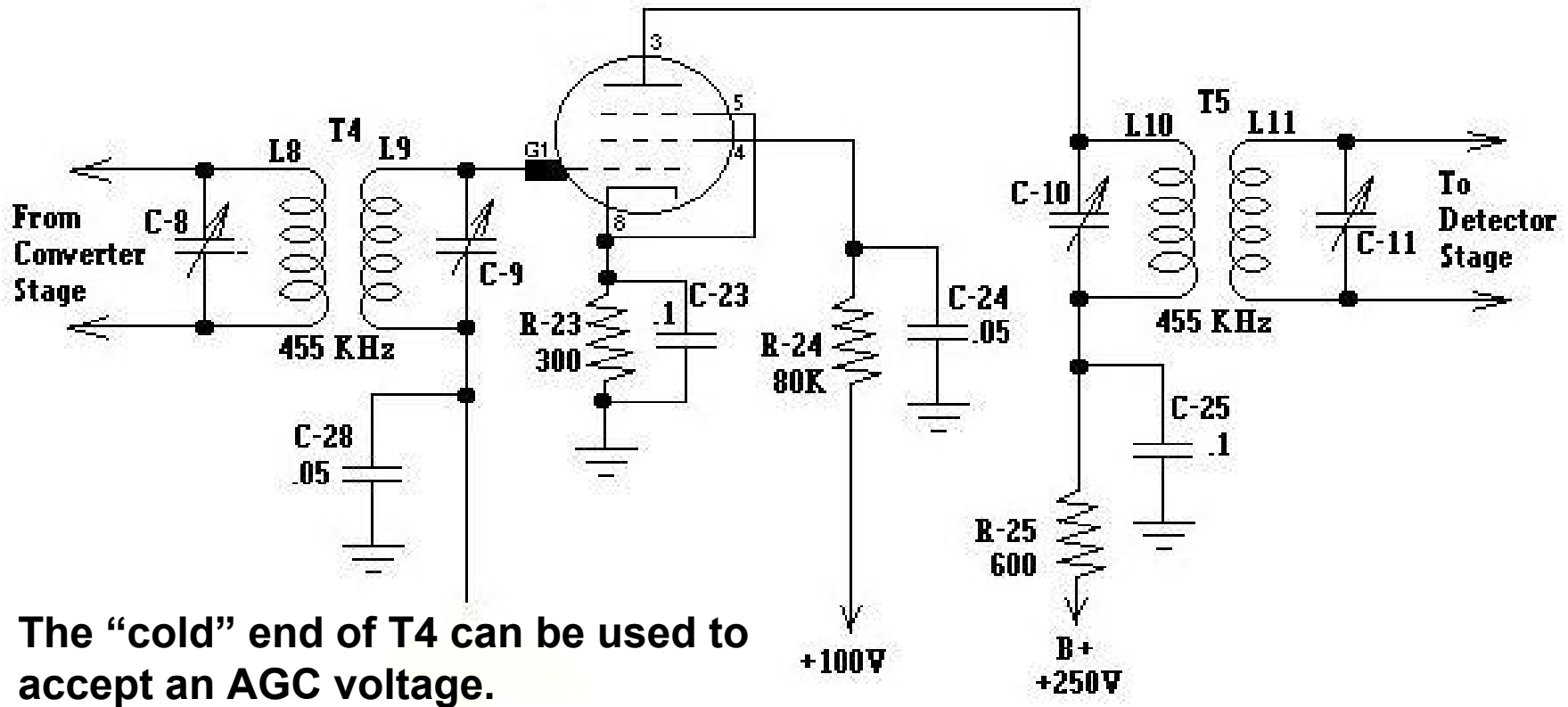
The "cold" end of T4 can be used to accept an AGC voltage.

Most receivers have more or less standard IF frequencies.

AM receivers, for example, usually have IFs at 455 kHz. Many Heathkit receivers have their IF at 3395 kHz. FM receivers typically use IFs at 10.7 MHz or 11.5 MHz.

Many Japanese ham radio transceivers use 9 MHz as the IF.

There is also a trend to use IF frequencies that are quite high, such as 45 MHz or 63 MHz.

A basic AM radio usually uses a 455 kHz IF. To receive a station at 1020 kHz in the AM broadcast band, for example, the oscillator (adjusted by the set's tuning dial) would need to be at 1475 kHz (most LOs operate above the desired signal to be tuned).

Example: oscillator freq = 1020 kHz + 455 kHz = 1475 kHz.

An AM station operating at, say, 970 kHz on the dial would be rejected.

1475 kHz LO – 970 kHz = 505 kHz. The 505 kHz won't pass through the sharply tuned IF transformers. As such, the station at 970 on the dial is rejected.

No discussion of heterodyne mixing in receivers would be complete without a brief explanation of *images*.

Let's say there's an AM net in your neighborhood in the 160 meter ham band. Assume it meets at 1.93 MHz.

If the signal at 1930 kHz reaches your receiver's antenna, and the LO is still set at 1475 kHz to receive the desired station at 1020 kHz on the AM dial, *image interference* may occur.

1930 kHz - 1475 kHz = 455 kHz!

The signal on 160 meters will ride through and cause what us Radio Amateurs hate: QRM!

The only way to reject the offending image is to provide good selectivity at the receiver's front-end amplifier, using good tuned LC circuits there.

**Note how the image frequency is at twice the IF frequency.**
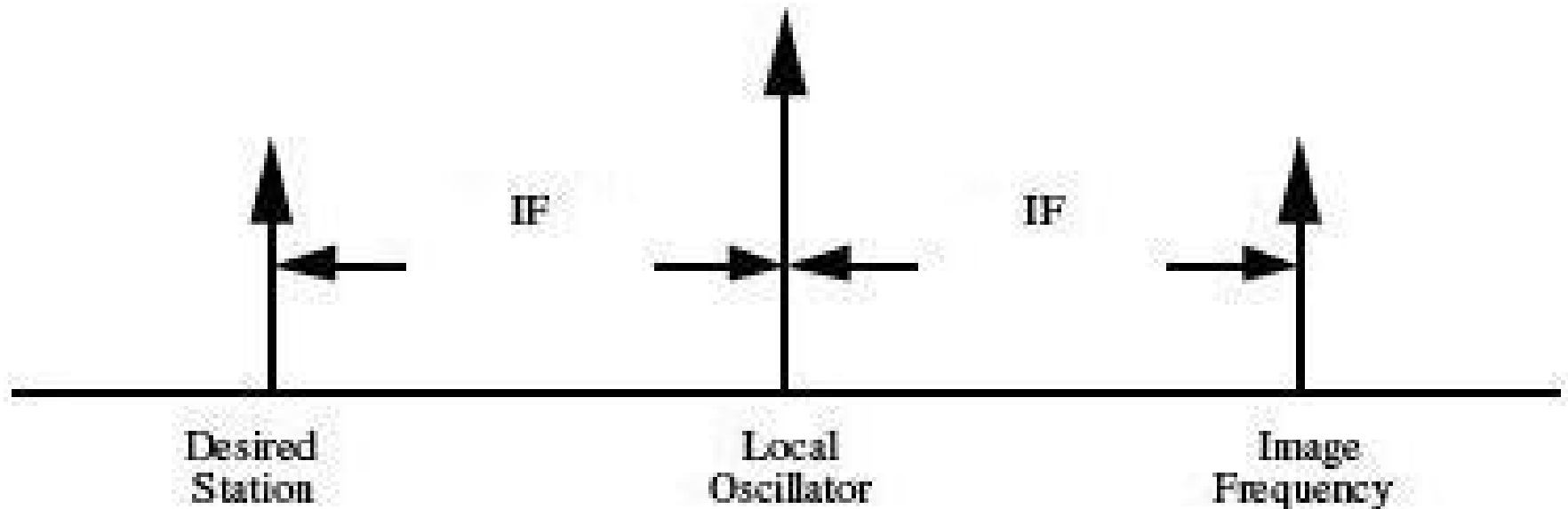
There's a nifty image calculator on-line at:

www.arcticpeak.com/radiopages/imagefrequencies.htm

The *image rejection ratio*, or image frequency rejection ratio, is the ratio of the IF signal level produced by the desired input frequency to that produced by the image frequency.

The image rejection ratio is usually expressed in dB. A good front-end filter helps reject images. A bandpass filter can also pass an entire ham band while rejecting out-of-band images.
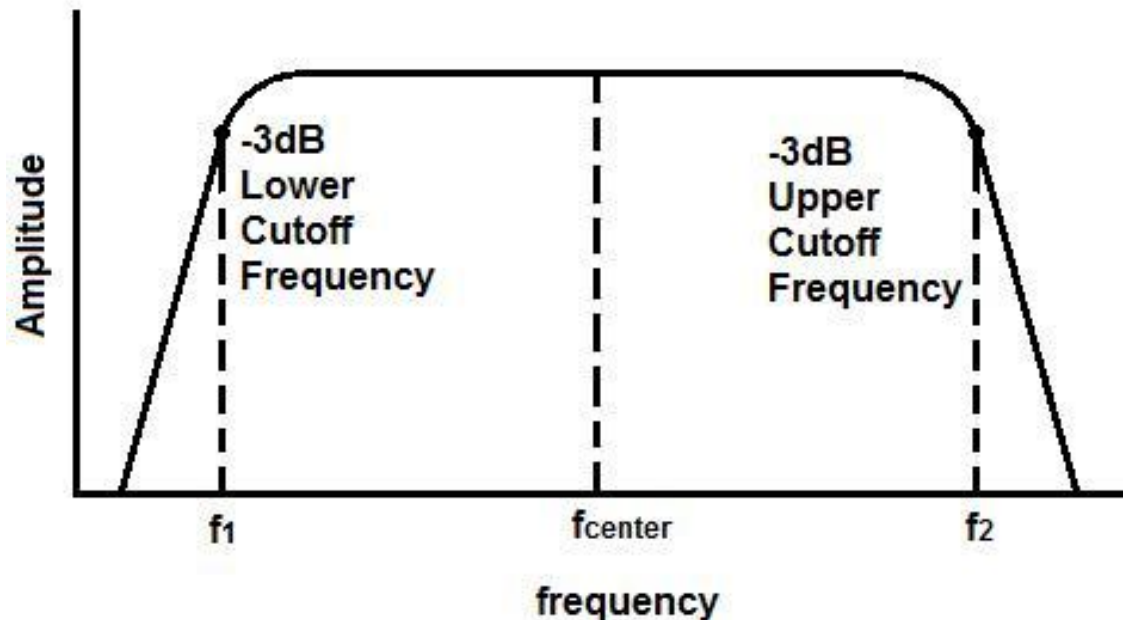
There are also special circuits that some radio manufacturers use; they're called *image-reject mixers*. They're more complex than simple mixers.
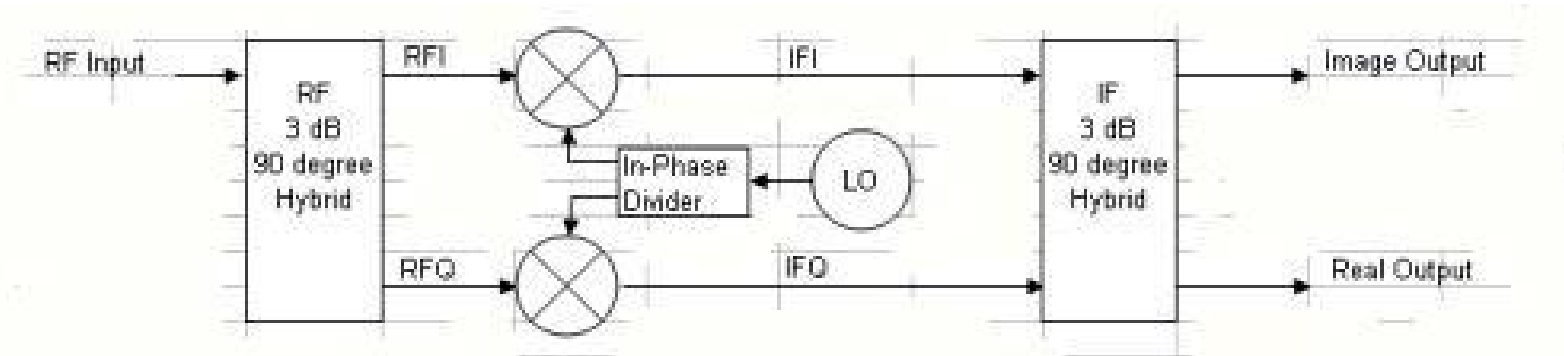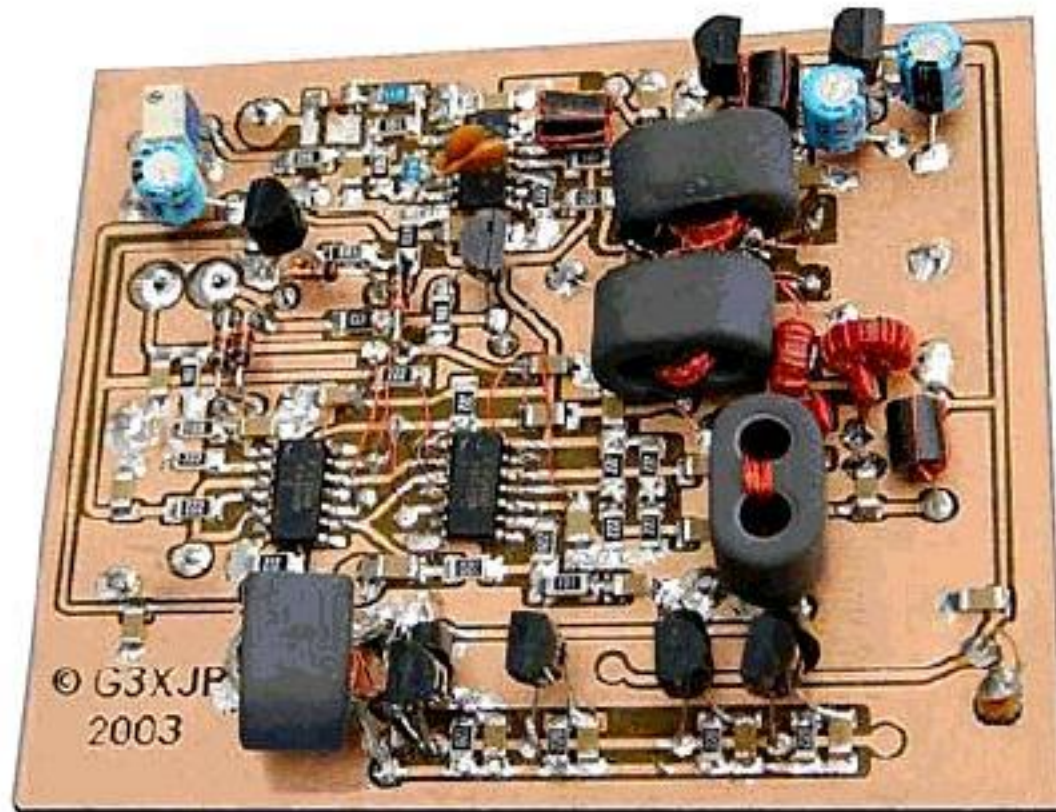

Image-reject mixers are often used in microwave receivers.

Here's a switching mixer on a home made circuit board for use in the *G3XJP PIC-a-STAR* transceiver project for the HF bands.

Until next time, 73 de AI2Q