

## Receiver Operation at the Component Level

### Unit 9. Activity 9.4. How a Receiver Works

**Purpose:** The objective of this lesson is to allow the student to explore how a receiver works at the component level. Beginning with the receiver description at the block level, the student will be able to identify individual components within each block of the receiver and describe the component function in basic terms.

**Overview:** Electronic devices can at first glance appear to be complex, however, if the device is broken down into individual circuit blocks and each block studied, the operation of the device becomes more clear and simplified. In turn the individual blocks are re-assembled into the whole with a better understanding of the overall device. The same is true at the component level. If the individual components of a block are studied, then when they are re-assembled back into the block, there is better understanding of the operation of the block. This lesson is an extension of the previous lesson where the Tin Ear Receiver was studied at the block level. In this lesson, each block is studied at the component level.

**Time:** An average of one class period should be required for each block. The power supply block and the RF input block could be combined into one one-hour class period. The Detector and Local Oscillator blocks could require additional time. It is advisable that the students have already explored the basic building blocks of electronics lessons using the project activity board so that they already have a basic understanding of the functional block.

#### Skills Required:

Writing  
Critical Thinking  
Organization

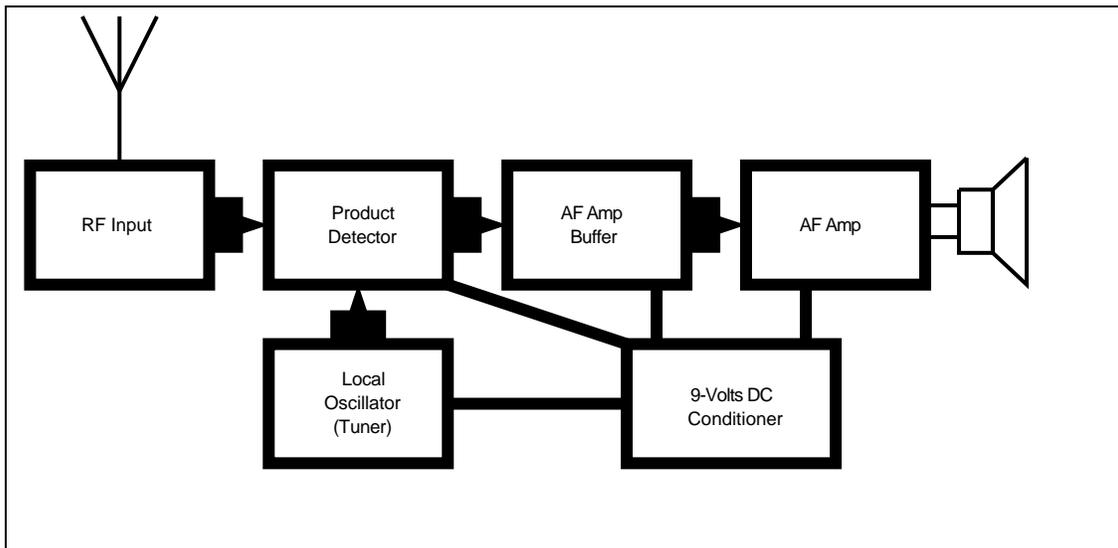
**Materials and Tools:** The students should have already built the TinEar Receiver kit and have used the receiver to listen to signals. The project activity board and digital oscilloscope with the associated lessons would provide additional background information.

**Preparation:** As stated, the basic building blocks of electronics lessons should be a prerequisite for this lesson. The students should have already built the receiver kits. The receiver cases should be opened so that the components are exposed. Students should be provided with copies of the overall block diagram, the overall circuit diagram and the individual block circuit diagram extracts.

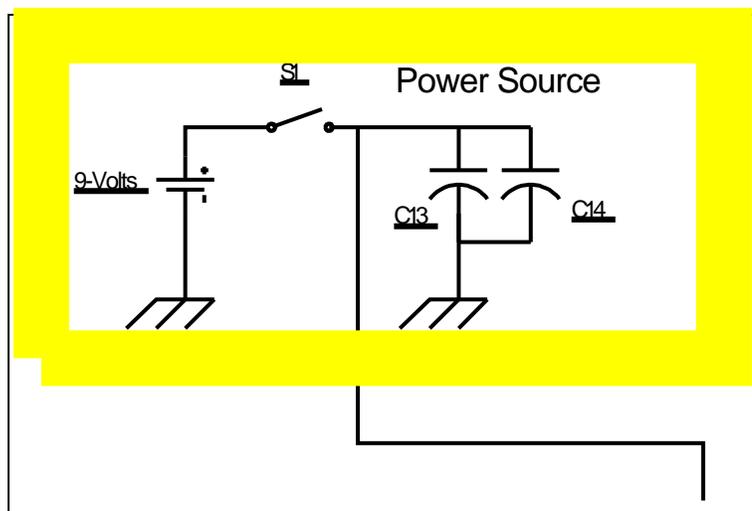
#### Background:

Project Curriculum Guide Activity 9.1.

The **block diagram** is a way to study a more complex electronic circuit. Electronic devices are usually made up of many sub-circuits that perform specific functions. These sub-circuits are called blocks. In many cases, the basic operation of an electronic device can be understood by understanding how each block functions and how each block functions within the device to produce the desired outcome. It is not necessary to understand how each component within the block functions, just how the overall block functions. This is the basis of integrated circuit technology. There are hundreds and perhaps thousands of individual components within a single integrated circuit. But it is not necessary for the user to understand what is going on within the integrated circuit, just how that circuit performs and interacts with other circuits. The integrated circuit is treated as a “black” box. Inside the TinEar Receiver, there are basically six blocks. The function of each block has been studied in the previous lesson. In this lesson, these “black” boxes will be opened and the student will study what is going on within each box (block).



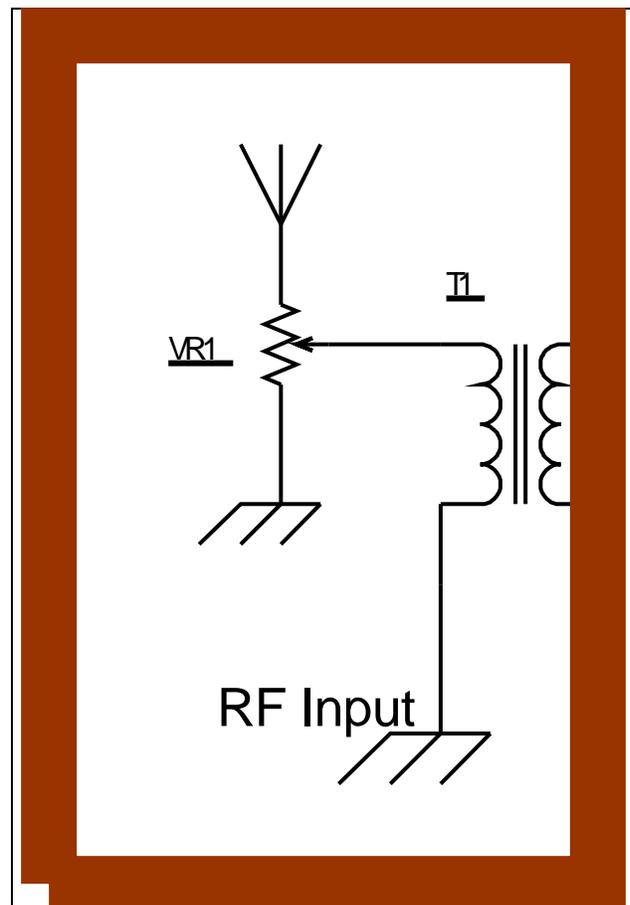
**Power Source:** The first block is the power source, in the TinEar; the power source is a 9-volt battery. The on-off switch is a convenient way to connect power to the system. If the power were left on all of the time, even when not using the receiver, the batteries limited life expectancy would expire and the battery would have to be replaced.



The battery produces a DC voltage, and it is important that the DC power source be as pure as possible. You have learned in previous lessons that electronic devices use both DC and AC voltages, as is the case of the TinEar receiver. Sometimes it is good to mix DC and AC voltages, but generally it is not a good idea to mix AC and DC in the power source. Because there is a chance that some of the AC produced by some of the other blocks within the TinEar can get back to the power source, it is a good idea to anticipate this and add filtering components to prevent this from happening. The capacitors C13 and C14 act as filters. Remember capacitors will pass AC but block DC, so the capacitors serve as a short circuit to ground for AC, but not DC. Therefore any unwanted AC on the power supply is shorted to ground.

Why the two different values of capacitors? From previous studies of capacitors as components, you learned that though capacitors pass AC voltages, how well they pass AC voltages depends on the frequency of the AC being passed. (The technical term for this variation is Reactance. Reactance is the AC equivalent of Resistance in DC.) As the frequency of the AC wave and/or the capacitance value increases, the reactance of the capacitor decreases. Therefore the high value capacitor provides a ready path for unwanted low frequencies and the lower value capacitor provides a ready path for unwanted higher frequencies

**RF Input.** Voltage produced on a receiving antenna by the intercepting radio waves is incredibly small, on the order of millionths of a volt. Normally there is a radio frequency (RF) amplifier required just after the antenna to boost the voltage of the incoming signals. In the simplified circuit of the TinEar, the RF from the antenna simply passes through a variable resistor to the following stages and there is no amplifier here. (Amplification comes a little later in the circuit) The variable resistor acts like a volume control so that the operator can use to control the amount of RF that is passed from the antenna into the receiver, and therefore the volume. The variable resistor acts as a voltage divider. When the wiper is all the way to the top (connected directly to the antenna) all the RF received by the antenna is passed through to the other receiver circuits. When the wiper is all the way at the bottom (connected to ground), no RF is passed. The positions in between essentially provide volume control.



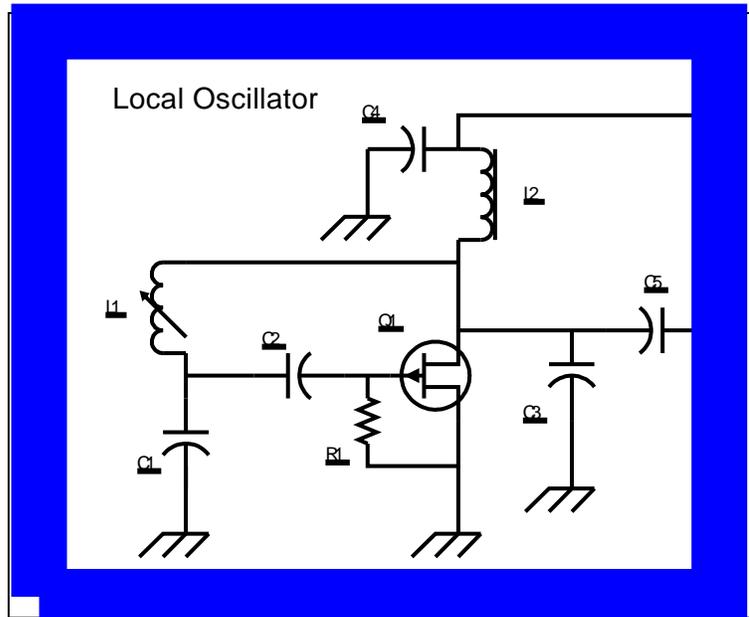
**Local Oscillator:** The radio is tuned by the use of the local oscillator. The local oscillator produces a radio signal that has the identical frequency of the radio signal that is desired to be tuned in. There will be additional discussion of why this duplicate radio signal is required later. For the time being, understand that the user tunes in the desired radio frequency or channel that will be heard by tuning the local oscillator to create a signal at the same frequency,

There are three main components that make up the local oscillator. The first two components are the inductor L1 and the capacitor C1.

When a current energizes an inductor, energy is stored in a magnetic field that surrounds the inductor. When the source of current is removed, the energy stored is returned to the circuit as the magnetic field collapses.

When a capacitor is energized, energy is stored in an electric field that is developed between the plates of the capacitor. When the source of current is removed, this energy is returned to the circuit as the electric field is discharged. When inductors and capacitors are connected together, the stored energy and alternately released energy cycle causes each component to be a source and acceptor of energy from the other component. The back and forth energy exchange between the inductor and capacitor occurs at a specific frequency and the pair resonates like a ringing bell. Specific values of inductors and capacitors resonate at specific frequencies that can be predicted by mathematic relationships and formulas. In the local oscillator, the inductor is a variable inductor. The brass screw that is advanced into and withdrawn from the center of the coil of wire changes the inductance of the component. Changing the inductance changes the resonant frequency of the inductor/capacitor pair and therefore the frequency.

The oscillating voltage from the inductor and capacitor pair is passed to the third major component of the local oscillator, the Field Effect transistor (FET), Q1. Q1 is an electrically controlled valve that amplifies a generated AC wave to about +/- 5-volts. The output of Q1 is allowed to pass through capacitor C5. Capacitors C3 and C4 act as bypass capacitors to filter out unwanted AC signals from the power source for Q1 so that the output is pure. The inductor L2 passes DC from the power source to the circuit while blocking the generated RF from contaminating the power source.

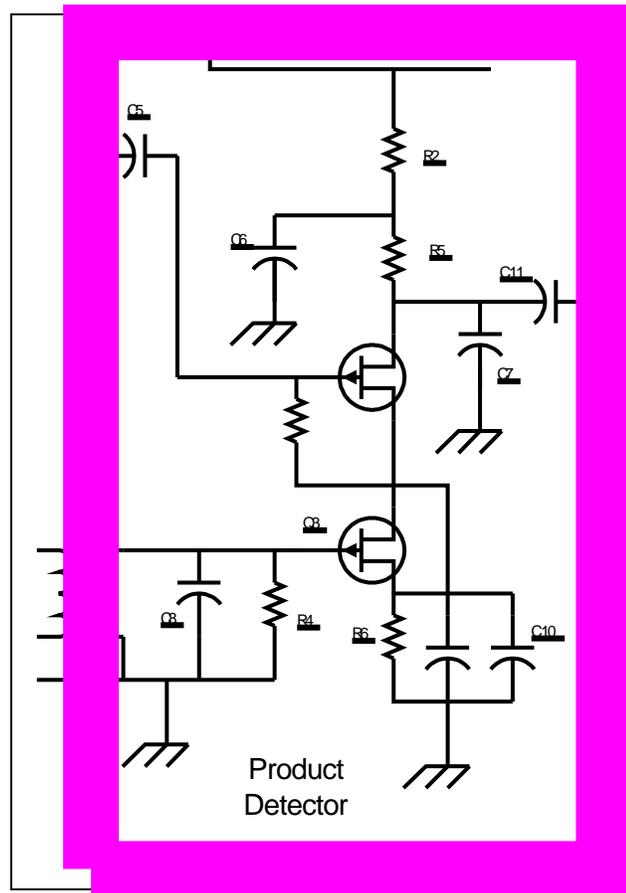


**Product Detector.** Two signals are now present in the receiver, one from the antenna that has the carrier RF wave plus the intelligence impressed on the wave. We will assume the intelligence is in the form of voice. The other wave is the RF wave of the same frequency as the incoming carrier that is produced by the local oscillator. If these two signals were combined so that the RF waves cancel each other out, the only thing left

is the imbedded intelligence. The circuit that does this combination is a mixer circuit; in the receiver the mixer is a product detector.

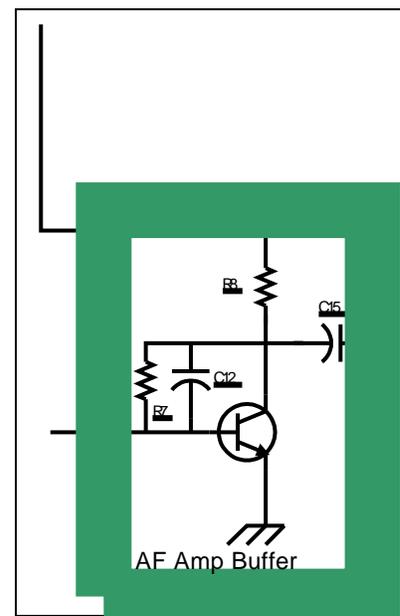
A detector is used to remove the carrier RF wave; a product detector is a specialized circuit in the mixer circuit family of circuits.

The RF wave from the antenna is applied to the detector Q3 through a transformer. The two inductors of the transformer are in close physical proximity that allows the individual magnetic field to cross over the inductor windings and thereby causing current to flow in the secondary winding inductor of the transformer. The RF from the local oscillator is applied to detector Q2 through the capacitor C5. Q2 and Q3 operate opposite of each other, when the applied waves are combined through Q2 and Q3, the waves cancel each other. The input waves however are not identical, the wave from the antenna has the intelligence impressed on it, that intelligence (voice) is not canceled out and remains.



The capacitors in the circuit again bypass unwanted RF from corrupting the power source to the FETs. The resistors are biasing resistors. Biasing means that the operation voltage ranges of the device are adjusted so that the device operates in the linear range. When a FET or transistor is operating in the linear range that means that any amplification or change of the signal input to output is done faithfully, without added noise or distortion.

**AF Buffer.** The output of the product detector is now just the voice intelligence we want to listen to. The detector is a very sensitive circuit and if it is forced to work too hard, the circuit will not perform correctly and noise and distortion of the signal may result. Therefore a buffer circuit is next in line that takes the output of the detector and boosts the signal a little without making too heavy a demand of the detector (little or no load). Capacitors C11 and C15 pass the AC signals into and out of the buffer while blocking the DC power source voltages. R7 and R8 are biasing resistors that make sure the transistor Q4 is





2. Explain how a capacitor can block DC voltages while allowing AC voltages to pass through the component.
3. Explain in your own words how the TinEar radio is tuned.
4. Draw an example waveform that is amplified in the linear range of a transistor and one that is distorted in the non-linear range.
5. Draw an example of the waveforms at various points of the receiver: antenna, local oscillator, inside the product detector, at the AF buffer, input to the AF amplifier, output to the earphones, and the power supply.

**Adaptation for special needs:** There will have to be verbal descriptions of the circuits and waveform developed for the visually impaired student.



