Educational Project Pack
Design Brief

KI0232EP
3 STAGE FM TRANSMITTER

Curriculum & Standards Framework Systems (Producing) Level 5.

At the completion of this project a student will be able to:
- Plan and carry out a production process according to instructions, with minimum waste materials
- Test the operation of the project and develop it as a part of a system

AREAS OF STUDY
Systems, Materials & information, Investigating, Designing, Evaluating & Producing

Tekky Kit

Designed and Supplied by

tekky .com.au

ElectroTech Brands Pty Ltd

www.electrotechbrands.com.au

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Note: 9V Battery (BA1822) not included in the kit

Brief description of circuit operation.

This project on transmitters offers you a new and exciting study.
A radio transmitter creates a wave of electromagnetic energy that carries information. This wave can be picked up (or received) in another place by a radio receiver and the information then used. The radio receiver is often referred to as a wireless, this is because in the early days of electronic communication a wire was connected between the transmitter and receiver to carry the information. With the development of the transmission of radio waves, no wire is used in between transmitter and receiver. Hence the term "WIRELESS" (wire-less transmission of energy).

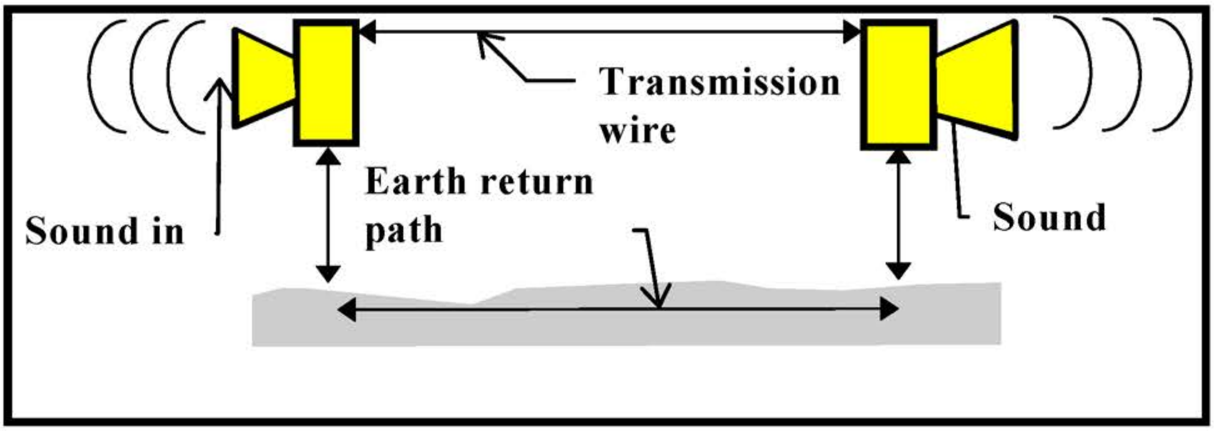


Figure 1. Single Wire Transmission System

Wireless transmission has the information placed on a 'Carrier Wave'. A carrier wave is necessary to allow the information to travel through space. A simple analogy would be like sending a parcel to someone via a truck; at the end we are only really interested in the parcel. In this transmitter we use FM or frequency modulation. More on this later.
The two types of modulation generally used in sending voice are FM and AM (amplitude modulation). FM varies the frequency and AM the amplitude of the carrier wave.

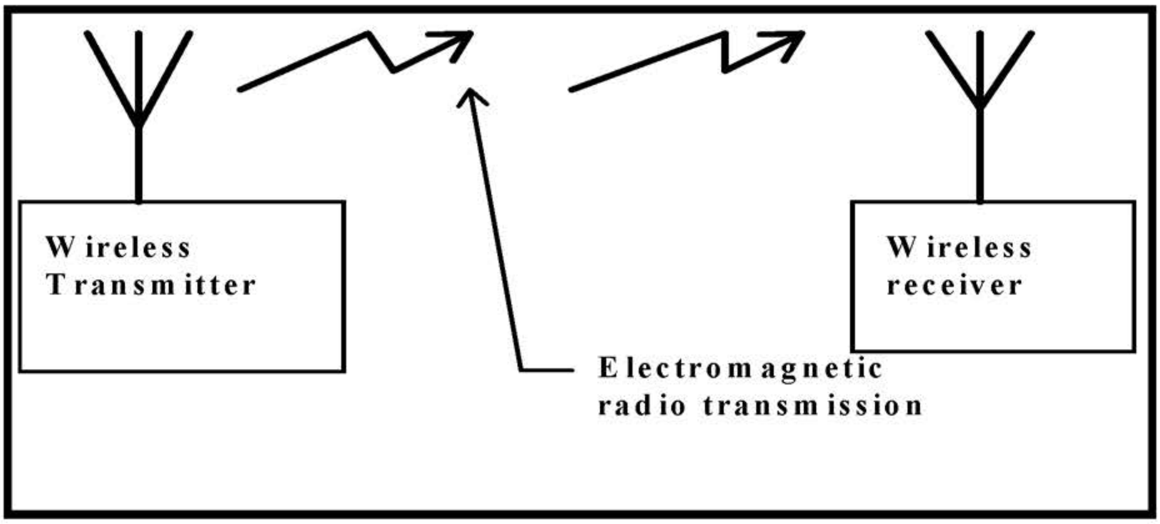


Figure 2. Wireless Transmission System

Pre-construction Assignment.

Name______________________________ Date____________________ Yr Level_______________

This part of your learning experience is related to “The Producing” in Frameworks.
Do the exercises below to guide you through your project.

Investigating:
From the details of page three, you may think of different ways to use the transmitter. List five below.
General hints: Safety, industry, the disadvantaged, entertainment, medical, environmental studies.

- ____
- ____
- ____
- ____
- ____

Designing:
Draw a picture in the space above, showing in simple form, how you think you would like to use your project. Eg: Using my example on page 3 as a guide draw a sketch of your idea.
Include a brief description below.

____
____
____
____
____

Component Recognition and Evaluation:

Activity 1.

In the circuit diagram on page 7 you will see the components for the questions below.

Questions:

- What type of component is R1? The value is written in as 4k7. (See Fig 3 Page 7.) Also find it on the table on page 8.)
- The value is written as 4k7. What is the value of this part?
- What is the meaning of the “k” ?
- What colours will be found on R2 assuming that it has a tolerance value of 5%?
- In the diagram on page 7, what is C1?

Answers:

- ____
- ____
- ____
- ____
- ____

Activity 2.

In the Wiltronics catalogue, use the index to find various components and identify and list ten types using the circuit of kit 32 for some examples. Include a note of the descriptions for future reference.

- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____

Activity 3.

Describe the difference between (a) a Primary Cell and (b) a Battery.

(a) Primary Cell:

(b) Battery:

Activity 4.

The circuit diagram is a schematic drawing. The components are drawn as schematic symbols. There are many schematic symbols. Investigate this area of knowledge. Draw and name five components in the area below, include a drawing of the component and the symbol. Include components in KI0232 circuit diagram (Figure 3 on page 7).

CIRCUIT DESCRIPTION

The transmitter picks up the audio from its surroundings with an electret microphone, the signal from the microphone is then fed to the first transistor Q1 which performs as an audio amplifier stage.
Output from this first stage is fed into the next which is an oscillator comprising of transistor Q2 and a resonant circuit (L1 coil and the yellow and white trimcaps, C6 and C12). The coil and capacitors are able to be tuned to your desired transmitting frequency.
Junction capacitance of the transistor Q1, varies with the applied voltage to its base, so the audio from the first stage causes the junction capacitance to vary (modulate) which in turn causes the frequency of the oscillator to vary (modulate).
The oscillator circuit is connected in what's called a Hartley configuration.
The modulated signal from the oscillator is then applied to the last stage using transistor Q3, as an amplifier of the signal to feed more power to the antenna.

TRANSMITTER OPERATION

This Three-Stage FM Transmitter has an RF stage in its output to amplify the modulated signal. By using a suitable antenna it has a range of up to 1 kilometre.

The transmitting range is dependent upon a number of variables.

- Location of the transmitter, (inside, outside, metal buildings).
- Single wire or dipole antenna.
- Power supply voltage.

The transmitter is constructed on a single-sided printed circuit board (PCB) with a silk screen overlay on top to aid in component placement. A solder mask on the copper side helps in soldering of the components.

ELECTRET MICROPHONE:

This is a capacitive type of microphone comprising of two dielectric plates. One is a permanently charged dielectric plate made of a ceramic material that has been heated and allowed to cool in a magnetic field. The other plate is formed by the diaphragm on the front of the microphone case. Sound pressure moves the front plate and this vibration of the plate changes the capacitance resulting in a changing voltage that is fed to a Field Effect Transistor amplifier built inside the microphone case.
Electret microphones have excellent sensitivity, a wide frequency response, are low in cost and small in size.

AUDIO AMPLIFICATION STAGE:

Capacitor C1 isolates the microphone from the DC base voltage of the transistor Q1 but allows the alternating audio signal from the microphone pass to be amplified by Q1 which is operating in a self-biasing common emitter mode.The output signal then comes from the collector of Q1 and feeds the oscillator stage.

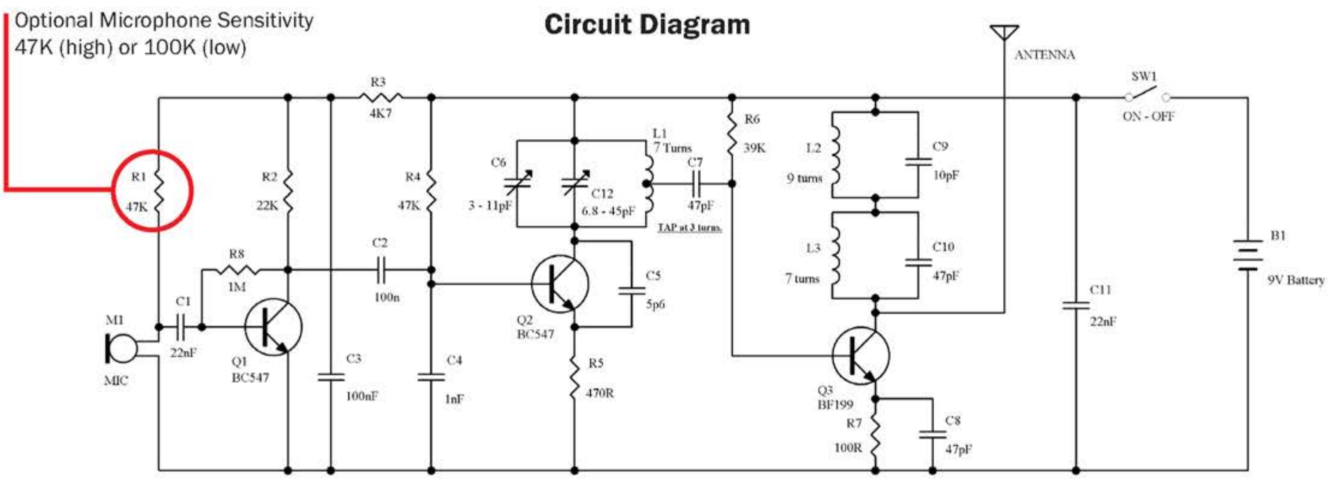
OSCILLATOR STAGE:

The oscillator stage is where the RF carrier is produced and modulated by the audio signal from Q1.
The resonant circuit (L1, C12, and C6), the transistor Q2 and the feedback capacitor C5 are the oscillator circuit here. An oscillating current flows around the resonant circuit.

The circuit oscillates because of feedback occurring though C5. The feedback signal makes the voltage across R5 vary and hence the base-emitter current of the transistor Q2 vary at a resonant frequency thus causing the emitter-collector current to vary at the same frequency. This current helps maintain oscillation in the resonant circuit.

Resonant circuits are sometimes called LC or 'tank' circuits. This comes from the ability of the LC circuit to store energy for oscillations. In a pure resonant LC circuit (one with no resistance) energy is not lost. However in a real AC network the resistive elements will dissipate electrical energy, such as wire and joint resistance and dielectric losses.

Circuit Diagram



The purely reactive elements, the C and the L, just store energy to be returned to the system later.

Note that the tank circuit does not oscillate just by having a DC potential put across it. Positive feedback must be provided in this case by C5.

TRIM CAPS:
To enable the oscillator to tune the full range of the FM broadcast band two trim caps are fitted into the circuit.

The Yellow trim cap is used to tune the transmitter to a clear part of the band and the White can be used to fine tune the transmitter to the desired frequency.

You can also change the frequency by altering the space between the coils of L1. Spread the L1 coil wide apart.

FINAL AMPLIFICATION STAGE:
This RF stage adds power to the RF signal. We use a BF199 RF transistor to accomplish this.

L2 (an RFC - radio frequency choke) and capacitor C9 in parallel are placed so as to prevent any RF signal from reaching the positive voltage rail, if it did then RF would be fed back to the input and unwanted uncontrolled oscillation would occur.

L3 and C10 are resonant at the transmitter frequency and adjusting L3 to set the resonant frequency correctly will allow the circuit to amplify the RF signal to its maximum. The adjusting of L3 can be done with the peaking circuit provided and described at the end of this set of instructions.

Component List

Designator	Part Description	Part No.
C1,C11	22nF Ceramic Capacitor	CC0153
C7,C8,C10	47pF Ceramic Capacitor	CC0121
C6	6.8-45pF Trimmer Capacitor Yellow	CC9028
C2,C3	100nF Mono Capacitor	CC0049
C4	1nF Ceramic Capacitor	CC0137
C5	4p7 (5pf) Ceramic Capacitor	CC0109
C12	3-11pF Trimmer Capacitor White	CC9023
C9	10pF Ceramic Capacitor	CC0113
MIC	Electret Mike, 2 Pin	MI2000
Q1,Q2	TO-92 NPN 300mW Transistor	BC547
Q3	TO-92 NPN 500mW Transistor	BF199
R1	47K 0.25W Resistor (Yellow, Purple, Orange) **OR** 100K 0.25W Resistor (Brown, Black, Yellow)	RS1685 RS1725
R4	47K 0.25W Resistor (Yellow, Purple, Orange)	RS1685
R2	22K 0.25W Resistor (Red, Red, Orange)	RS1645
R3	4K7 0.25W Resistor (Yellow, Purple, Red)	RS1565
R5	470R 0.25W Resistor (Yellow, Purple, Brown)	RS1445
R6	39K 0.25W Resistor (Orange, White, Orange)	RS1675
R7	100R 0.25W Resistor (Brown, Black, Brown)	RS1365
R8	1M 0.25W Resistor (Brown, Black, Green)	RS1845
SW1	DPDT Push ON - Push OFF Switch	SW1845
B1	9V Battery Snap	BA9000
HUW	2 Metre Grey Wire For Antenna	CB2201GRY
L1,L2,L3	35cm Enamelled Wire for Coils	CB2665
RF Detector Circuit - Components		
C1	100pF Ceramic Capacitor	CC0125
C2	100nF Mono Capacitor	CC0049
D1,D2	DO.35 Silicon Switch Diode	1N4148
PCB	FR4 PCB	PC9232

Assembling the Kit.

The kit can be assembled in any order but it is recommended that the coils and electret microphone be added last.

To keep the PCB small all resistors are inserted vertically. Use care and make sure the transistors are placed in their correct positions and the right way round.

The electret microphone is polarized and has to be fitted with the pin that is connected to the microphone case, connected to the '-' hole at the MIC position on the PCB.

MAKING THE COILS
The transmitter uses 3 coils (L1, L2 and L3) and the wire to make them is supplied in the kit.

The coils are made out of the red enamel covered wire provided. The red enamel paint insulates the wire so that when it is wound into a coil the turns can touch each other and not create a short circuit.

All three coils are wound on a 3mm-diameter former, a 3mm-drill bit for example using the smooth end that usually goes into the drill chuck.

It is best to make these coils as you are about to fit them to your circuit board because the drill bit can help you fit the coil to the board without causing any damage to it (fit coil to pcb before removing drill bit).

Coil	Wire Type	No of Turns
L1	Enamelled Copper	7
L2	Enamelled Copper	9
L3	Enamelled Copper	7

The following picture shows the wire wound on a 3mm drill bit, note the direction of winding the wire. If wound in the wrong direction it won't fit properly onto the circuit board.

Leave about 5mm of wire leading away from the coil so that it can be soldered onto the circuit board, next the red enamel needs to be removed where it is going to be soldered.
This can be done with a soldering iron and some solder.

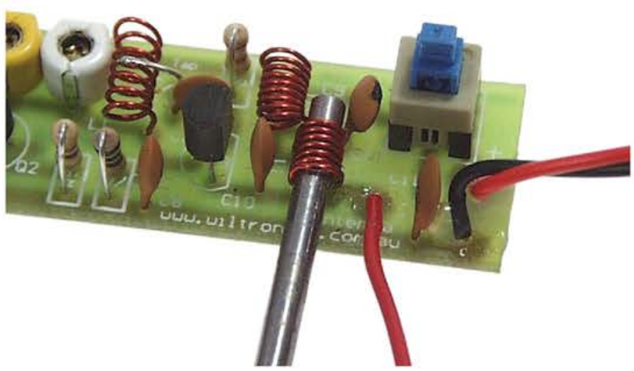
Firstly place the coil so that the wire ends point way from the bench top then place the soldering iron tip against the side of the enamelled wire, after about 3 seconds apply a little solder. Moving the tip around the wire should burn off the enamel and tin the copper wire underneath.

Depending on how hot the iron is this may take a little longer. Remember to clean the tip of the iron after you have removed the enamel from the wire.

Coil L1 also has to have some enamel removed from the top of the centre turn to allow a wire to be soldered to it. You can either scrape away the enamel with a knife while it is on the drill or wait until the coil is soldered into position on the PCB and the windings opened up and use the soldering iron method described earlier.

The circuit board is layed out so that you can leave the coil on the drill bit and solder it into place using the bit as a guide to steady and not damage the coil.

When fitting L1 you will have to spread the windings a little to get it to fit, about 1mm space between each turn is enough and this can be done while the coil is still on the drill.



A connection (or tap) is required from the middle of the L1 tinned copper wire coil to the pad marked TAP next to the coil. Solder a piece of wire, about 1cm long, into the "tap" hole. It should be long enough to reach over the top of L1 to the middle turn. Bend the wire so it touches the top of the turn then solder it in place.

OPERATING VOLTAGE
The FM Transmitter was designed to operate from 9V DC, however you can increase the output power by using a 12 or 15V DC supply. If you try this then the values of some resistances will have to change. You can experiment by changing the component values shown.

Supply Voltage	R3 Value	R5 Value	R6 Value	R7 Value
9Vdc	4K7	470R	39K	100R
12 to 15V dc	10K	560R	68K	150R

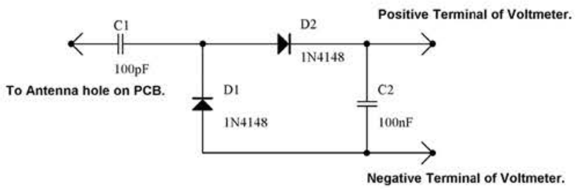
TUNING THE FM TRANSMITTER
Once you have assembled your transmitter you will have to tune it to a frequency on the FM broadcast band, a part of the band that is clear of local stations.

- Tune your FM receiver to a part of the dial where you cannot hear any radio stations.
- Turn "on" your FM transmitter, do not fit the antenna just yet, and preferably with an earphone connected to the receiver, adjust the Yellow trim capacitor until you hear your signal in the earpiece.
- By tapping the microphone you will hear your signal, if you don't then continue tuning until you can. Because the transmitter has a RF amplifier it can overload the receiver and it may sound like you have tuned to the right spot but tapping the microphone will make sure.
- Use the White trim capacitor to fine-tune the transmitter to the receiver.

Next you need to tune the RF amplifier as explained below.

PEAKING CIRCUIT.
To get maximum power out of the RF amplifier stage the circuit - coil L3 and C10 the 47pF capacitor - needs to be tuned to the oscillator frequency.

By making up the simple circuit below and using a multimeter the output of the RF amplifier can be measured.



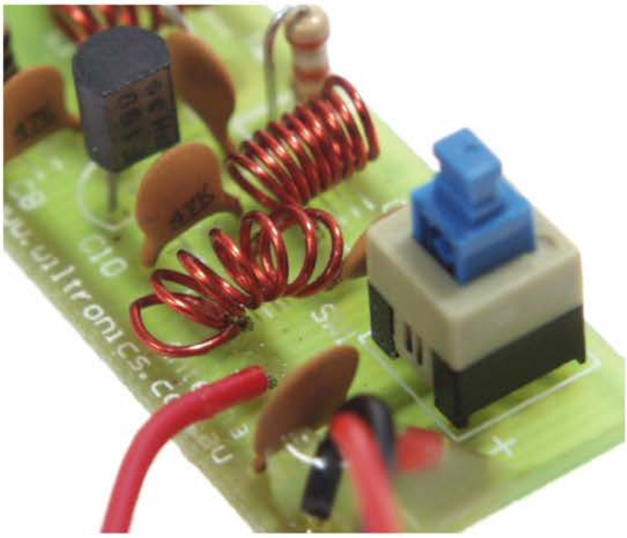
The circuit is simply a RF detector that uses diodes to charge a capacitor. A multimeter set to 2V or 20V DC will indicate the voltage level on the capacitor.

The components of the RF detector can be directly soldered to each other without any PCB. The output across C2 is to be connected to the multimeter's positive and negative terminals as shown. Solder the input of the circuit directly to the antenna wire hole on the PCB, using a 5cm length of wire.

Moving the turns of L3 apart or together will cause the meter reading to change. L3 is tuned when the windings are spaced to provide the greatest meter reading possible.

Note that while you are touching the coil the reading will be lower, only take your measurements after you have adjusted the coil.

You will find that if your transmitting frequency is down around 90 MHz then the coil turns will be close together, at around 107 MHz the windings may need to be spaced so far apart that the end coils are almost flat on the PCB surface (works best at low end of range—about 90MHz).



When you have peaked L3 for maximum output you can remove the circuit and solder the antenna lead in its place.

If you change transmitting frequency then you will need to repeat the peaking procedure in order to get maximum power output.

WANT MORE RANGE?

You can get more range as a trade off against stability and battery life.

- reduce R5 to 100R
- reduce R7 to 47R
- increase C7 to 470p

DIPOLE ANTENNA

The half-wave antenna (the length of wire about 160cm long) you are supplied with will give you quite good range. However a dipole antenna will work better and this is basically two wires attached to two points in the circuit, each point oscillating 180degrees out of phase with each other.

The antenna point and the positive of the battery are two points that you can connect to. A dipole antenna can be made from your existing antenna by cutting it in half, ie, two 80cm lengths, leave the half soldered into the antenna point and soldering the other free half to the +9V pad. Point the two wires in opposite directions.

WHAT TO DO IF IT DOESN'T WORK

Have you turned the switch 'on'?

Check your soldering, particularly around the leads of the coils, any enamel left on them can cause problems. Use a strong light if necessary.

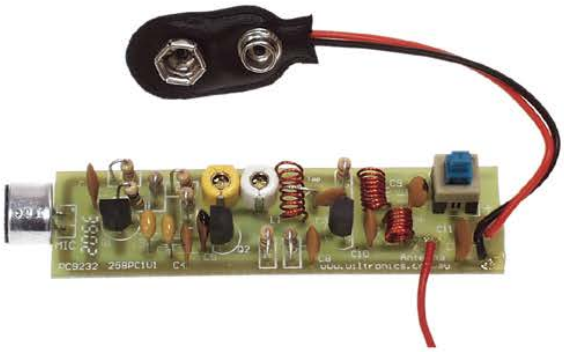
Check that you have placed the components in their correct positions on the PCB.

Is the connection to the middle turn on L1 made cleanly and securely?

Check for any solder connections (shorts) across solder pads that are next to each other and shouldn't be there.

Are the transistors the correct way round and in their proper places?

Have you really spread out the coils of L3? At the high frequency end of the FM broadcast band each end of L3 should just about be bent over and touching the PCB.



Frequency Modulation:
For those of you who do not understand what FM is, or how it is achieved, then this will get you started.
FM means "Frequency Modulation".

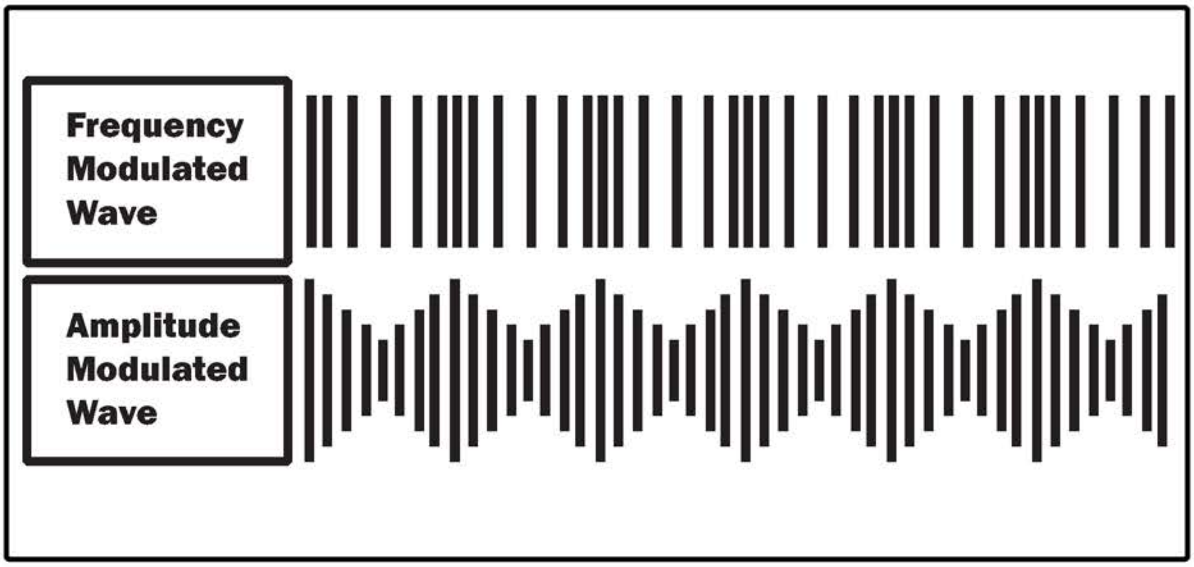


Figure 4.

Figure 4 gives an idea of the difference between AM and FM. The carrier wave frequency and amplitude is kept constant in both cases when no information is present. The top graph shows this clearly along the x-axis and you can see that the information is put on the Y axis. With AM the variations are up and down on the amplitude, so we have a saw tooth effect as shown. The information on FM however, is placed along the X-axis so it causes a variation in the frequency. The Y-axis remains constant. Since most interference is amplitude modulated, all we have to do with FM is trim the FM wave to a constant level and cut the interference off. This is called "clipping". It is easier to produce nice clear static free music with FM. If AM is clipped the in the same manner the information would be lost. The carrier is there to get the information out into the space between the transmitter and the receiver.

When the microphone is completely silent there will be no audio signal. At this time, the signal generated by the oscillator is a constant frequency. The bars in Figure 4 would be evenly spaced. With information on the carrier the bars are bunched at intervals. The AM illustration on the other hand (the top set of bars) varies by the height of the signal. This generated signal is known as the "carrier" because it is used to carry the audio or other signal out to the receiver/s. It is this frequency that we are interested in on the radio dial. We tune the radio into the carrier. If we alter the variable capacitor on the circuit, we can cause the carrier to change in frequency and change the tuning position on the dial. To prove that the carrier is still there without audio, you could take out the microphone or disable it. When you tune the radio in now, the speaker will suddenly become very quiet; this is because we have tuned into NO SOUND.

FM is achieved by causing this signal to deviate or "wobble about" the set carrier frequency. The change is in sympathy to the sound that enters the microphone. The Comrade is a transmitter. In the receiver the deviation is detected and DEMODULATED. When this happens the carrier is taken away by electronic means. The audio signal remains, it is further treated until it is converted by a speaker into sound.

What to learn from this project.

It should already be clear from the above circuit description that there is a surprising amount of electronics which may be learnt from this deceptively simple kit.
Here is a list of some advanced topics in electronics which can be demonstrated or have their beginnings in this kit:

- Class C amplifiers
- FM transmission
- VHF antennas
- Positive and Negative Feedback
- Stray Capacitance
- Crystal-locked Oscillators
- Signal Attenuation

The simple half-wave antennae used in the kit is not the most efficient. Greater efficiency may be gained by connecting a dipole antennae using 50 ohm coaxial cable. Connect one lead to the Antenna point and the other to the earth line.
You may experiment with using 6V or 9V with the circuit to see how this increases the range of the transmitter.
The sensitivity may be increased by lowering the 22K resistor to 10K. Try it and see. Note that this Tx is not suitable for use on your body, for example, in your pocket. This is because it is affected by external capacitance and the transmitting frequency drifts depending how close you are to it. Stray capacitance is automatically incorporated into the capacitance of the tank circuit which will shift the transmitting frequency.

Technical.

Construction of kit 0208 is on a single-sided printed circuit board (PCB).
Design of the kit was under Protel Autotrax a popular circuit drawing package.

Post-Construction Assignment.

Questions and activities to study the operation of this circuit.

- What is the purpose of the microphone?
- What is the most likely reason for a circuit to fail to work after you have assembled it?
- What is C1 used for ?
- What is the difference between TR1 and TR2?
- Why is the tuning circuit called a “tank circuit”?
- Draw the symbols to show the difference between a NPN transistor and a PNP transistor in the space below.

Answers:

- ____
- ____
- ____
- ____
- ____
- ____

Conclusion.

Now you should have completed some of the “Producing in your “Evaluating” phase.
Investigate further ways of improving the sensitivity of the FM transmitter. For example a wire grid used for a hanging basket from plant in a nursery could easily be used as a reflector for the microphone. All that would be needed is some aluminium foil to line the basket so that the microphone insert could be fitted in the same way as a torch globe.

Your report should develop your investigating and designing work. Look for opportunities to improve your project; perhaps by thinking and recording ways to make the design more presentable fitting it into a suitable enclosure or box.

Teacher Notes

Kit 0232 3V FM transmitter

Student Prerequisites
At least introduction to:

- Classroom behaviour.
- Identification to tools.
- Safe use of tools.
- Soldering practice on PCB.
- Knowledge of OHM's Law.
- Knowledge of resistor colour code.
- Identification of electronic equipment.
- Use of voltmeter, current meter, cathode ray oscilloscope.
- Component recognition.
- Introduction to schematic diagrams and symbols.

Investitgation Samples & References:

- Dictionary of Electronics E.C.Young. Penguin.
- Wiltronics Catalogue (Latest Edition)
- Curriculum Standards and Framework. Board of
- Studies Victoria.
- Protel Technology. Circuit drawings, diagrams.
- Teaching notes and Photography.

Answers to questions

Pre-construction Assignment:

Investigating:

- Roving microphone.
- Listener for a baby in another room.
- Distress transmitter.
- Remote noise pick-up for machinery.
- Remote bird and animal call pick-up in environmental studies.

Designing:
Individual answer.

Activity 1

- A resistor.
- Four Thousand Seven Hundred ohms.
- To show thousands by a shorthand method (k = 1000).
- Brown, Black, Green and Gold for the 5% tolerance value.
- C1 is a ceramic capacitor twenty two nanofarad (22nF) or piont zero two two microfarad (0.022uF)

Activity 2

- Electret microphone
- Resistor
- Capacitor
- NPN transistor
- Trimmer capacitor
- Coil
- Antenna (wire)
- Jumper Wire (Link)
- Battery
- Printed Ciruit Board

Activity 3
(a) A primary cell is a device that produces electricity by chemical means, consistinf of a pair of plate electrodes in an electrolyte
(b) A battery is a source of direct current or voltage consisting of two or more primary cells connected together and used as a single cell.

Activity 4
Individual answers.

Post construction exercises.

- The microphone is used to convert the sounds into electrical energy.
- Poor soldering.
- C1 blocks DC current from the microphone to the transistor and also passes the AC voice or sound signal.
- TR1 is a low frequency transistor and TR2 is an RF transistor. TR1 will not work as well in place of TR3 if at all
- Because it stores and releases energy.