

# Experimenting with ultrasonics

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Inexpensive ultrasonic transducers can be used in a fascinating variety of gadgets and circuits, from garage door openers to 'bat detectors'. This feature is especially for the experimenter.

MINIATURE ultrasonic transducers can be used to generate high frequency waves in air which cannot be heard yet which have a wide range of applications in remote control, short-distance communications and in the detection of intruders. This article reviews the type of circuits in which these transducers are normally employed and will provide the experimenter with plenty of ideas to try; practical circuits are given, without constructional details.

Two main types of ultrasonic unit will be discussed. **Transmitter units** are oscillators in which high frequency oscillations are fed to a transducer which produces ultrasonic air waves in much the same way as a loudspeaker produces audible air waves. If the waves from a transmitting transducer are allowed to fall onto a transducer in a receiver unit, very small signal voltages

are developed by the receiver transducer and these signals may be suitably amplified to operate a relay or an alarm. The relay can be used to switch any other equipment, but some receiver units include complex logic circuits.

The main limitation in the use of ultrasonic air waves is the limited range over which they can operate — usually not much more than 30 metres. Although microwave beams can be used over much greater distances, ultrasonic systems are far simpler and cheaper. In addition, the waves are not radiated far outside the room or region concerned.

### Frequencies

The frequencies used are usually in the range 20 kHz to 60 kHz. The average adult can hear frequencies of up to about 15 kHz, but some young people

can hear considerably higher frequencies, so this sets a lower limit of 20 kHz to 25 kHz. The uppermost frequency is set by the rapid increase in air absorption of the waves which occurs at frequencies above about 50 kHz and which limits the maximum range at which detection can occur. (Much higher frequencies — about 1 MHz to 10 MHz — are used in ultrasonic applications in medicine, whilst GHz ultrasonic frequencies can be used in acoustic microscopy, but no air transmission is then involved.)

Ultrasonic transducers can operate efficiently only near the resonant frequency of the ceramic piezo-electric element they contain. Most of the transducers on the market resonate at either 40 kHz or 25 kHz; the performance at these two frequencies is not so very different, but the 40 kHz ▶

types are more directional.

An ordinary sound wave around 300 Hz has a wavelength of the order of one metre, so it is diffracted at the edges of common objects whose size is not much larger than the wavelengths concerned. Thus, ordinary sound bends around the edges of objects. However, the wavelength of 40 kHz waves in air is only about 8 mm; this is much smaller than most common objects found in a room so the waves are effectively stopped by objects of dimensions greater than a few centimetres. In practice this means that the ultrasonic transducers are strongly directional, the output from an ultrasonic transmitting transducer being about 10 dB down at 30° from the direction in which the transducer faces. Similarly, the receiver sensitivity falls by a similar amount when the incoming waves are off the transducer axis.

In the open air, the ultrasonic transducers must be pointed approximately towards one another or little response will be obtained. In a room of a normal size, however, ultrasonic waves are reflected from walls and objects so that a single transmitter in a room will cause the whole room to be filled with ultrasonic waves.

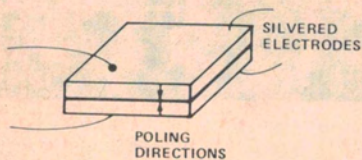
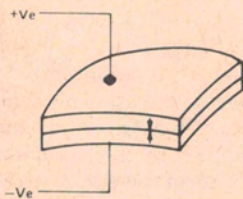


Figure 1. A piezo-electric ceramic element consists of two plates of opposite poling directions cemented together. When a voltage



is applied between the faces the plates bend and can transfer ultrasonic energy to the surrounding air.

## The transducers

An ultrasonic transducer consists of a square of piezo-electric ceramic material with metallized electrode surfaces deposited on its faces. The ceramic material is actually a bimorph element, which means that it consists of two separate layers fastened together, these layers having their electric dipoles aligned in opposite directions as illustrated in Figure 1.

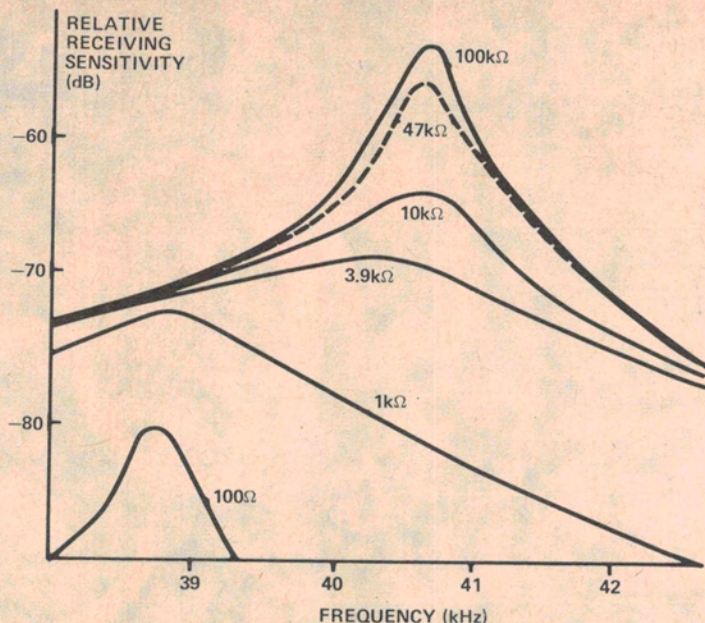


Figure 2. A set of curves showing how the frequency response of a sharply-peaked 40 kHz receiver transducer is affected by various values of load resistor.

The ceramic bimorph element is suitably mounted so that its vibrations are not damped by the mounting and is fixed inside a small case, which is usually cylindrical, measuring about 10-25 mm in diameter and about the same length. The front has an open mesh so that the ultrasonic waves can pass easily into or out from the ceramic element. If the transducer case is made of metal, the case should preferably be at ground potential.

The ceramic elements couple to the surrounding air with a reasonable degree of efficiency. The ultrasonic power output from a typical transducer can be of the order of 10% of the electrical power fed to that transducer.

Some suppliers offer types of ultrasonic transducer which are designed to be used as either transmitting or receiving transducers. Other types available have some differences between the transmitting and receiving transducers. Although the functions of these components may be interchanged, there will be some sacrifice in performance or in their safe ratings in many cases.

The writer performed some measurements on the frequency response of one type of transducer specifically designed for use in receiver units and obtained graphs similar to those of Figure 2, published by the manufacturer for various load resistors connected across the transducer terminals. It can be seen that if a load resistor of 10k is connected across the transducer terminals instead of 100k, a loss of about 10 to 12 dB in sensitivity results, but the bandwidth is considerably increased. At lower values of load resistor, the resonant frequency

is reduced somewhat, but normally the effective load should not be less than a few kilohms.

When transducers specifically designed for use in transmitter units were used as receiving units, it was found that they behaved in the unloaded state rather like the receiver transducers would behave when loaded with about 4k7 to 10k. Thus, the transmitter devices have much flatter response curves. Transducers supplied for use as either transmitters or receivers were also found to have fairly flat response curves. One may guess then, that a receiver unit with a sharply peaked response may be ideal for the detection of weak ultrasonic signals in the presence of noise, but transmitter units are more broadly tuned so as to ensure that they can cover the receiver frequency peak.

## Transmitter circuits

One of the simplest ways of constructing an ultra-sonic transmitter is to connect the transducer across the terminals of a signal generator set to the resonant frequency of the transducer. Either a sine wave or a square wave may be used, but care should be taken to ensure that the maximum permissible rating of the transducer is not exceeded. It is possible to use ultrasonic transducers under pulsed conditions, but care is needed to obtain good results.

It is possible to design oscillators for driving ultrasonic transducers using only a single transistor, but a feedback transformer is necessary and it is usually easier to design a two transistor astable circuit which requires no transformer. An astable circuit of this type, designed by Philips-Mullard for

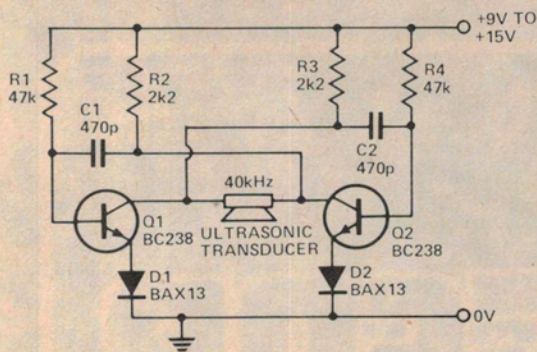


Figure 3. An ultrasonic transmitter using discrete components. Synchronisation with the 40 kHz transducer is automatic. For 25 kHz operation, C1 and C2 should be increased to about 750 pF (560 pF and 180 pF in parallel). Most silicon NPN transistors can be used for Q1 and Q2; e.g. BC108, BC548 etc.

their 36 kHz transducers, is shown in Figure 3. The diodes in the emitter circuits of the transistors suppress the reverse voltage peaks occurring between the base and the emitter; these peaks are likely to exceed the maximum permissible reverse value of 5 V for the transistor types shown and at the same time can give rise to frequency fluctuations. The diodes are not needed at low supply voltages, but the ultrasonic output is then lower.

The natural frequency of oscillation of the circuit in Figure 3 is determined by the time constants R1-C1 and R4-C2, but this natural frequency is made lower than the required frequency. When the ceramic piezo-electric element of the transducer is connected across the two collectors, the oscillations of the circuit make the transducer ring. The ringing transducer generates a voltage which causes premature triggering of a cut-off transistor so that the oscillator is synchronised to the transducer frequency. Thus, no trimming of the oscillator frequency is necessary in this particular circuit. Current consumption is about 5 mA with a 9 Vdc supply.

Circuits can usually be simplified by the use of integrated circuits instead of discrete components. Figure 4 shows how a 555 device can be used to drive an ultrasonic transducer at about 40 kHz. The preset resistor, VR1, should be adjusted for maximum current consumption which occurs when the 555 oscillator frequency matches the transducer frequency and maximum power is radiated. The 555 produces square waves with a mark-to-space ratio of about 1:1. If 25 kHz transducers are to be used, C1 should be increased to

1n5, alternatively R1 can be increased to about 18k.

Another simple ultrasonic transducer circuit is shown in Figure 5; it uses the 4001 quad two-input CMOS NOR gate. Two gates act as a square wave oscillator which drives the other two NOR gates in push-pull. The latter act as buffers and drive the transducer in push-pull, preventing any voltages from the transducer from affecting the oscillator itself. The oscillator frequency can be adjusted by means of the preset component VR1 so that maximum current is taken from the supply line. Capacitor C1 should be increased to 270p for 25 kHz operation.

The performance of each of the oscillators shown in Figures 3 to 5 inclusive is very similar.

More complex transmitter units can be made which radiate a modulated waveform or a pulse-coded waveform. For example, a 556 device (dual 555)

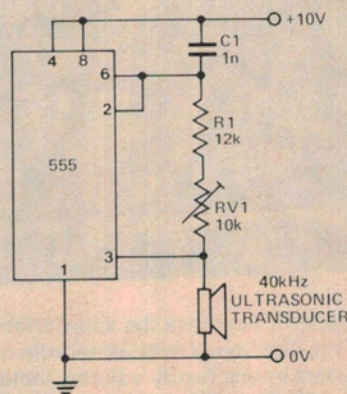


Figure 4. A transmitter circuit employing a 555 timer/oscillator IC. For 25 kHz operation, C1 should be increased to about 1n5.

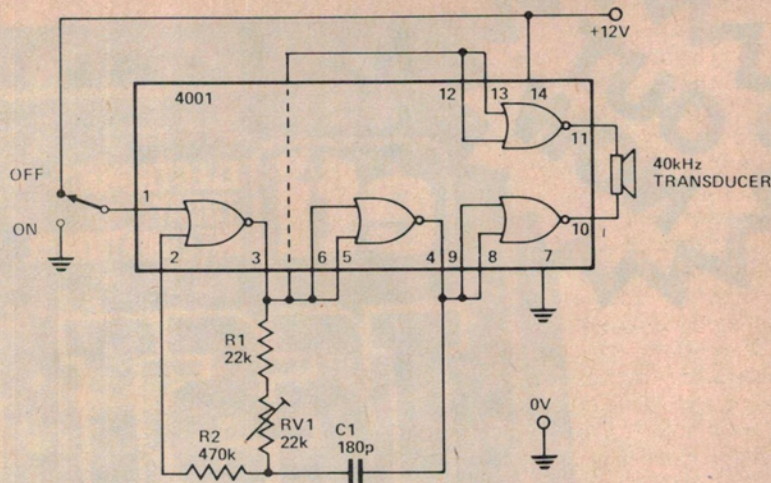


Figure 5. A CMOS 4001 push-pull transmitter circuit. For 25 kHz operation, C1 should be increased to about 270 pF. A CMOS 4011 NAND gate can be used instead of the 4001 device but the ON and OFF connections to the switch are then reversed.

can be employed to generate a 300 Hz signal to modulate the second 40 kHz oscillator of the 556; the advantage of using modulated ultrasonic waves is that the receiver can be made selective to the 300 Hz modulating frequency and reject noise.

## Receiver units

In the same way that the ceramic piezo-electric bimorph element bends when a voltage is applied across it (Figure 1), when ultrasonic waves fall on it, the bending of the element generates a small voltage across the transducer terminals. This voltage is a 40 kHz waveform, but unfortunately the amplitude is quite small. When the transmitting and receiving transducers are placed face-to-face and touching one another the voltage across the receiver transducer terminals is typically less than one volt, but at a distance of about 30 meters the voltage across the receiving transducer falls to some tens of microvolts and any further increase in the distance between the transmitter and receiver will be likely to result in the signal being lost amongst the noise.

Thus, it is clear that an amplifier of considerable gain must follow the receiving transducer in the receiver unit. This amplifier may consist of discrete transistors, but the circuit can be considerably simplified by the use of one or more integrated circuits. In particular, it is interesting to note that the ICs developed for the amplification of 10.7 MHz IF signals in FM receivers, or for amplification of the inter-carrier sound signal in television receivers, are very suitable for the amplification of ultrasonic signals from a receiving transducer.

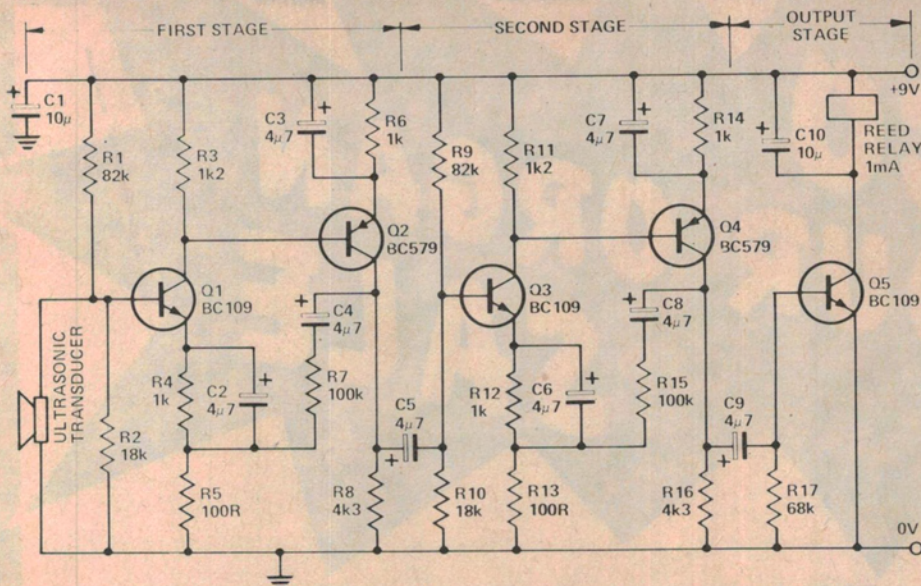


Figure 6. An ultrasonic receiver circuit using discrete components. The reed relay closes when ultrasonic waves fall onto the input transducer.

### Discrete components

A five-transistor discrete component receiver is shown in Figure 6. Each of the transistors employed is a high-gain, low-noise, small-signal type of the appropriate polarity. Q1 and Q2 provide the first stage amplification and this is followed by an identical second stage, Q3 and Q4, while Q5 controls a sensitive reed relay. When ultrasonic waves of the correct frequency (25 kHz or 40 kHz) fall on the transducer, the relay will operate.

The transducer can be connected directly to the base of Q1, since it has a very high dc impedance and will not affect the bias applied to Q1. The gain of the first stage is determined mainly by R7 and R5 and that of the second stage by R15 and R13. Either R7 or R15, or both, should be reduced if the circuit becomes unstable due to a poor layout or if a high sensitivity is not required.

When the distance between the transmitting and receiving transducers is quite small, it is possible to use only a single stage of amplification before the output stage.

When the 40 kHz voltage peaks across R17 exceed about 0.65 V, Q5 commences to conduct and only a little increase in the ultrasonic wave intensity will then cause the reed relay to close. Capacitor C10 smooths out the 40 kHz half-cycles of current passing through the reed relay.

It is important to note that a very sensitive reed relay must be employed in this circuit which closes with a current of no more than about 5 mA with a coil voltage of about 6 V. During the setting up of the circuit and when experimenting with it, it is instructive to insert a 10 mA meter in series with the reed relay coil. Although the reed relay can switch only a small current (perhaps 100 mA), this current can be

used to perform any desired operation, including the control of a much larger relay.

### TAB231 Receiver

Another receiver circuit for the control of a relay is shown in Figure 7. A TAB231 (SGS-ATES) or the equivalent, uA739 (Fairchild) or a similar device, is employed as a 40 kHz two-stage amplifier. Resistors R1 and R3 provide a bias for the non-inverting (+) input of the left-hand amplifier to which signals from the transducer are also fed. Capacitor C1 effectively ties the junction of R1, R2 and R3 to common (0V) as far as alternating voltages are concerned, so the resistor R2 appears as a load across the transducer terminals and broadens the frequency response of the transducer (see Figure 2).

The gain of the first 40 kHz amplifier stage is set by the ratio of R5/R4, but the other components in the feedback network reduce the gain at low frequencies. The output from pin 1 is fed directly into the non-inverting input of the second amplifier stage and also provides a suitable bias for this input. The second stage is of a very similar design to the first stage except that some component values are modified to reduce unwanted noise and low-frequency gain which can cause problems.

The output from pin 13 is fed through C7 to a diode pump circuit. The latter converts the 40 kHz waveform into a steady voltage which appears across the diode pump output capacitor C8 which has its upper end positive when the ultrasonic waves are present on the receiving transducer. Each 40 kHz input wave passing through C7 causes a small amount of charge to flow through D2 to the capacitor C8 which thus becomes charged.

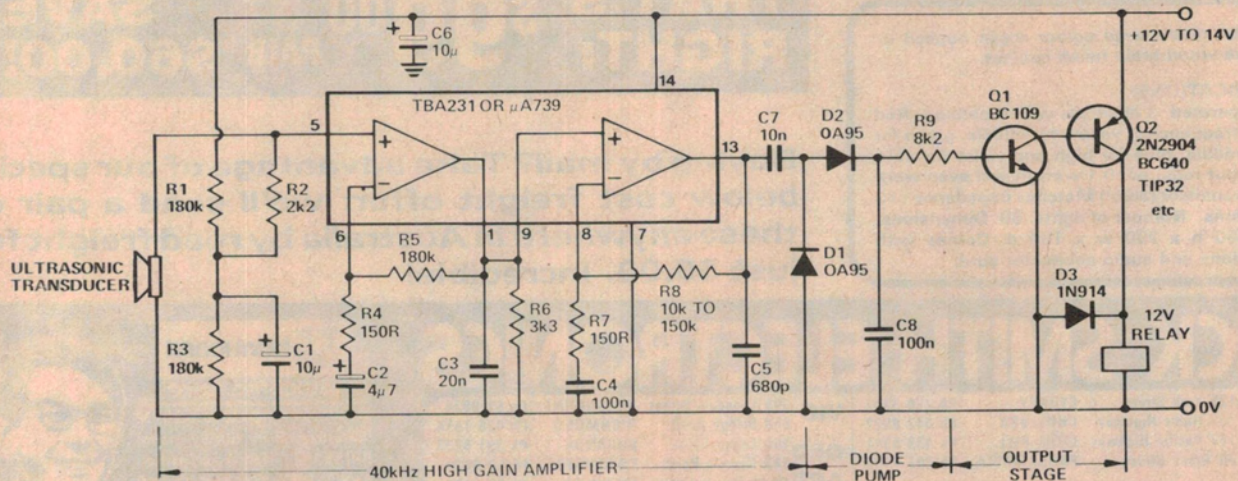


Figure 7. Receiver circuit using the TBA231 or uA739 as a high gain amplifier.

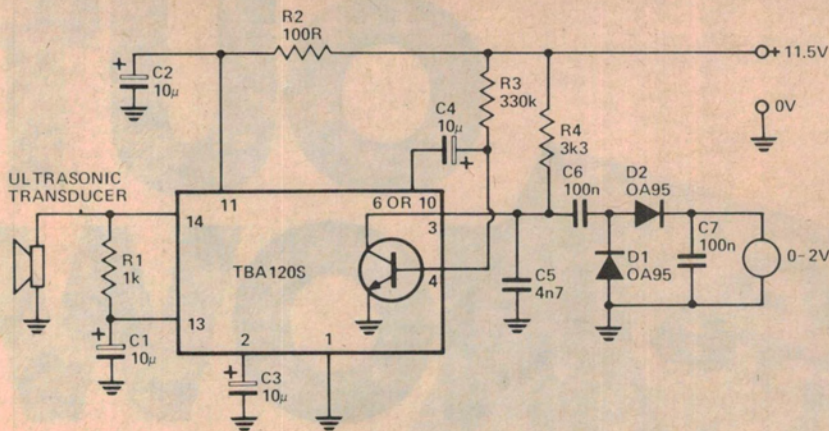


Figure 8. A receiver employing the TBA120S as an amplifier and featuring a meter display.

Charge from C8 passes through R9 and through the base-emitter junction of the high-gain transistor Q1; a collector current therefore flows in this transistor. The current flowing from the emitter to the base of the PNP output closes whenever ultrasonic waves fall onto the receiving transducer. The 2N2904 output transistor can switch a moderately large current, so a relay which requires a current of 150 mA or more can be employed. Such a relay can switch a substantial current through its contacts — perhaps 10 A in a 250 Vac circuit, so power levels of well over 1 kW can be controlled by this circuit directly.

The resistor R8 in Figure 7 may be adjusted to obtain the required gain. If the sensitivity is too high, spurious signals may cause the relay to close. In particular, the ringing of a telephone bell, even at a distance of some eight metres can cause the closing of the relay. The sensitivity can be reduced by reducing the value of R8. For some applications it is instructive to insert a meter (perhaps 100 mA FSD) in the 2N2904 emitter or collector circuit.

Transducers resonating at any frequency between about 20 kHz and 60 kHz may be employed in the circuits of Figures 6 and 7 with the component values shown. It is only in the transmitter circuits that component values must be slightly changed if transducer frequencies are altered so that the required frequency of oscillation is obtained.

### TBA120S circuit

The circuit of Figure 8 shows how a Philips TBA120S device may be used as a 40 kHz amplifier. The TBA120S is intended for use as an IF amplifier and an output may be taken from pin 6 or pin 10 through a 10nF coupling capacitor, as shown, to the base of an internal transistor which is used to provide more

gain. In the circuit, R4 forms the collector load and the capacitor C5 was found to be needed to prevent spurious oscillation.

The output of the diode pump in Figure 8 is shown connected to a 2V FSD meter, but it could also drive a two-transistor output stage such as that shown in Figure 7. Indeed, the parts of

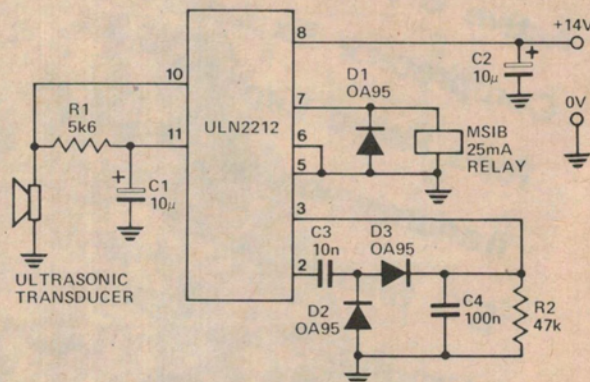


Figure 9. This is one of the simplest possible circuits that will operate a relay from an ultrasonic transducer. The relay should be a sensitive type and may have whatever contact set is appropriate to your application.

the circuits shown in this article can be regarded as building blocks which the experimenter can connect together in many different ways, although care may be needed to prevent oscillation.

### ULN-2212 circuit

A very simple receiver circuit for relay control can be made using one of the devices intended for use as a combined intermediate frequency and power amplifier (leaving any volume control circuit unused). The writer has used the LM1808, while the circuit of Figure 9 shows the use of a Sprague ULN-2212 device.

The section of the ULN-2212 intended for use as an intermediate frequency amplifier is used to amplify the 40 kHz signal from the ultrasonic

transducer, the bias to the input pin 10 being applied through R1 from pin 11.

The output from pin 2 is coupled to the diode pump, D2 and D3, and the resulting positive potential is fed into the input of the power amplifier at pin 3. This power amplifier can pass enough current to control the relay connected in its output circuit (pin 7). As with the circuit in Figure 7, a diode is connected across the relay to shunt the reverse transient voltage produced when the relay coil current ceases to flow, since this voltage could damage the output device.

Although the circuit of Figure 9 is very simple, it is not so flexible or so sensitive as that of Figure 7.

The diodes shown in the diode pump circuits are germanium point-contact types (OA95), since these are switched to conduction by a potential of about 150 mV. Silicon diodes, such as the 1N914, can also be used in the diode pump circuits but they may not respond to weak signals as do the pump circuits using OA95s since they require about 0.65 V for forward conduction.

### Applications

The receiver circuits of Figures 6 to 9 inclusive can be employed in simple remote control applications in which one wishes to be able to press a button on a small hand-held transmitter unit in order to cause a relay to close in some equipment up to about 20 metres away. Unlike light beams, ultrasonic communications links are almost unaffected by the presence of rain, fog, snow, smoke or dust. Such a link could, for example, be used to call a person working in a garden shed into the house.

If an ultrasonic transmitter unit is mounted on the front bumper of a car, when the driver reaches his home he can transmit a short pulse of ultrasonic waves to a receiving unit near his garage door which causes his garage

door to be opened automatically by a motor, without the necessity for the driver to leave his vehicle. Similarly, he can close the garage door as he leaves home.

Ultrasonic links have been widely used for the remote control of television receivers, but they have now been largely displaced by infra-red links. The latter tend to be more complex than ultrasonic links, but they do offer the wider bandwidth desirable for the many channels of communication required to control a colour television receiver (which may possibly include a Teletext decoder).

If an ultrasonic transducer is placed in a sealed enclosure, such as the interior of a car or a refrigerator, a receiver unit fitted with a meter in its output stage can be moved around the outside of the enclosure to locate any small leaks in the sealing rubber. The ultrasonic waves can only escape from the interior through any such small leaks and this method of leak detection is generally much more convenient than, for example, waiting until it rains to see where the water enters one's vehicle!

The circuit of Figure 8, or the circuits of Figure 6 or 7 (if fitted with a meter output) are very suitable for this application.

Leaks in pressure or vacuum pipes generate ultrasonic waves which can be used to deflect a meter in a suitable receiver. Thus the leak can be located. Similarly, some types of electrostatic corona discharge produce ultrasonic waves which can be detected in much the same way. Generally however, it is better to convert the ultrasonic frequency into an audible frequency by a heterodyne technique, as discussed later.

A simple transmitter and receiver of the types discussed, operating at a fairly low gain, can be used as an intruder detector. If an intruder passes through the beam, the interruption of the beam operates a relay and this gives the required alarm. Ultrasonic systems have the advantage that the intruder cannot hear the signal. However, the Doppler system to be discussed is normally much more satisfactory than a simple transmitter and receiver, since the Doppler detector is triggered by movement anywhere in a protected room and it is not necessary for the intruder to actually pass through any given point in the beam. Nevertheless, a simple transmitter-receiver is adequate for the protection of a corridor or other narrow area through which an intruder must pass.

Another application for an ultrasonic transmitter-receiver circuit is the

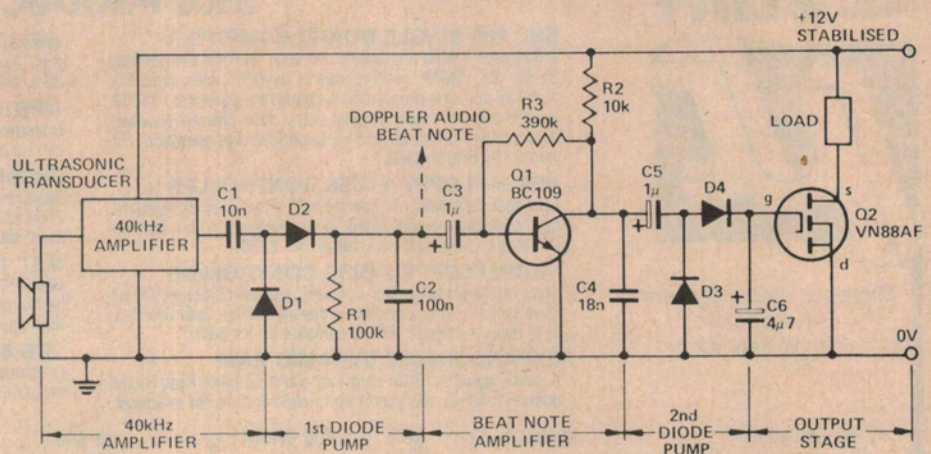


Figure 10. Circuit of a receiver for a Doppler-type intruder detector.

remote control of slide projectors. If one wishes to have remote control without connecting wires merely so that one can cause the next slide to be projected, a simple system like those described will suffice. If, however, one wishes to be able to return to an earlier slide and to be able to alter the focusing in either direction, then a four-channel link is needed. Multi-channel systems are most easily constructed using some of the special devices developed for television receiver control.

At one time, the police in certain countries used ultrasonic transmitters to switch on motorway warning lights for fog or ice by merely directing the beam at a receiver near the warning light without stopping their vehicle.

Another application is in vehicle safety belt security systems in which the safety belt emits an ultrasonic tone from a transducer fixed to it; the vehicle cannot be started unless the signal is being received by a transducer mounted near the windscreen. Slightly different frequencies cover the driver and front passenger seats.

## Doppler intruder detector

A Doppler intruder alarm receiver circuit is shown in Figure 10. When used with one of the transmitter circuits discussed previously (which should be operated from the same stabilised power supply), the circuit can detect the slightest movement anywhere within a room of the size found in a normal house. The 40 kHz amplifier shown in block form may consist of the discrete circuit shown in Figure 6, up to and including Q4 (so that C9 of Figure 6 corresponds with C1 of Figure 10). Alternatively, the 40 kHz amplifier may consist of that shown in Figure 7, in which C7 corresponds to C1 of Figure 10.

The ultrasonic transmitter is placed in the same room as the Doppler receiver unit of Figure 10, but the two transducers should not be placed so that they directly face one another. The transmitted frequency is reflected around the room from wall to wall and some of the signal will be picked up by the receiver unit. If anything moves in the room, a Doppler-shifted ultrasonic tone will be reflected from the moving object to the receiver so that the two separate frequencies will be amplified by the 40 kHz input amplifier.

The output from this amplifier is fed to the first diode pump circuit so that the difference frequency or beat note is developed across C2. Objects which are moving fairly rapidly in the room develop a beat note in the audio frequency band which can be heard if the signals across C2 (Figure 10) are fed to an audio amplifier. More slowly moving objects develop sub-audio frequencies but the use of large coupling capacitors in the remainder of the circuit ensures that a response to either audio or sub-audio frequencies is obtained. Ultrasonic frequencies are shunted to common through C2.

The beat frequency is coupled by C3 to a single transistor difference frequency amplifier, Q1. Any residual 40 kHz frequency components are filtered out by C4 and the low difference frequency is passed to the second diode pump circuit. This circuit will develop an appreciable voltage across C6 only when a Doppler shifted signal is present at the input in addition to the transmitted signal. The presence of the Doppler-generated signal across C6 can be used to switch on the VN88AF power MOSFET output stage which allows a current to flow through the load and thus sound the alarm.

The power MOSFET output stage of

Figure 10 has been included as an alternative to the two-transistor circuit of Figure 7. The output stage of Figure 7 can be used as the output of the Figure 10 Doppler receiver, and vice-versa.

The writer has also used a circuit of type shown in Figure 10 with a power Darlington output stage controlling a relay. The relay did not close if a person some four metres from the equipment remained absolutely still, but if he breathed in or out (even relatively slowly), the movement of his chest wall was enough to cause the relay to close without fail!

One of the problems with such extreme sensitivity is that of false alarms, since even the occasional false alarm in the middle of the night can cause a great deal of trouble! One should also remember that this circuit is sensitive to any stray ultrasonic frequencies such as the ringing of a telephone bell or even the rubbing of two surfaces together if they are near the transducers. If the transducer of the Doppler receiver of Figure 10 (or the transducer of any sensitive ultrasonic receiver) is tapped with the finger, a considerable response will always be obtained in either an output relay or output meter. It should be noted that a regulated power supply should be used for the Figure 10 circuit, otherwise stray changes in the power line voltage may give rise to false alarms.

The 40 kHz amplifier can be the same type as that used in Figure 6 or Figure 7, its output being fed to the diode pump of the Figure 11 circuit. In addition, signals from an oscillator operating at a frequency close to the frequency of the incoming signals are fed through C2 to the same diode pump circuit. The oscillator circuit can be that of Figure 4, but the output from pin 3 is connected to C2 of Figure 11 instead of to the ultrasonic transducer shown in Figure 4.

The difference frequency between the incoming signal and the oscillator is developed in the non-linear diode pump circuit of Figure 11. The components C3 and C4 filter out the ultrasonic frequency signals and the difference frequency is passed to an audio amplifier through the volume control VR1. Any audio amplifier with a gain of the order of 50 is suitable (such as many of the integrated circuit audio amplifiers on the market). Either a small loudspeaker or an earpiece may be used to produce the audible noise.

Experimenting with a 'bat detector' circuit is of great educational value and makes one appreciate what a vast world of ultrasonic tones we are missing! If one rubs the palms of one's hands together or rubs any two suitable surfaces in front of the face of the receiving transducer, one can hear the rubbing noise, since such rubbing

required when receiving the ultrasonic waves from rubbing two objects together since the range of frequencies generated by such objects beat with one another.

The oscillator is required when receiving a note from an oscillator connected to an ultrasonic transmitting transducer (such as the circuits of Figures 3 to 5). The use of a transmitter with the bat detector circuit of Figure 11 results in a clear note being produced which it is easy to pick out amongst the noise. The writer found that the note could be detected when the distances between the transmitter and detector were as much as 35 metres in the open air. The maximum distances indoors are greater, since there is less stray ultrasonic noise to interfere with the wanted signal. In particular, ranges in a corridor can be considerably increased by reflections of the ultrasonic waves from the walls towards the receiving transducer. A further increase in the range can probably be obtained by placing the transmitting transducer or the receiving transducer, or preferably both, at the focus of parabolic reflectors.

It is interesting to note that bats emit ultrasonic vibrations between about 25 kHz to almost 160 kHz, whilst small rodents can emit vibrations from about 90 kHz down into the audible range. Insects such as grasshoppers and some moths emit frequencies up to about 80 kHz — 100 kHz. Some of these vibrations can be detected by the Figure 11 circuit, but for optimum results a purpose-built bat detector costing about \$1000 is needed. The writer has used the Figure 11 type of circuit to detect the ultrasonic emissions from young mice a few days old by which they communicate with their mother.

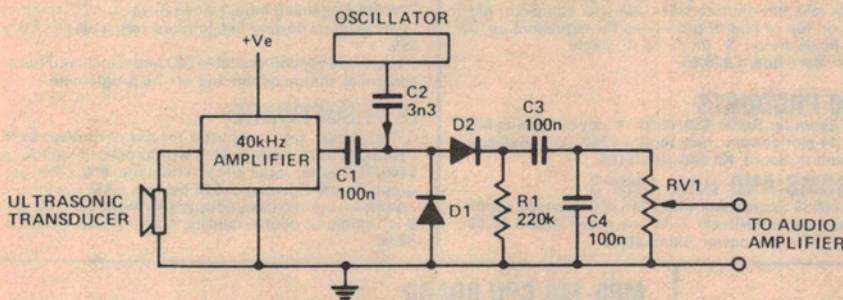


Figure 11. Ultrasonic sounds can be rendered audible by 'heterodyning' the input to an ultrasonic transducer down to the audible frequency range. The frequency range covered depends on the particular transducer employed; i.e. a 25 kHz or a 40 kHz type.

## Bat detector

A 'bat detector' converts incoming ultrasonic waves into audio signals which can be heard. In order to construct a bat detector which will respond to a wide range of ultrasonic frequencies, an expensive ultrasonic microphone is usually needed. However, reasonable results can be obtained using a cheap ultrasonic transducer in the type of circuit shown in Figure 11. No transmitter unit is needed.

generates ultrasonic waves. Snapping a finger and thumb together or blowing air through one's teeth are other simple ways of generating ultrasonic waves.

The performance of the Figure 11 circuit does not vary very much as one changes from 40 kHz to 25 kHz transducers, although one is listening to different frequency bands in the two cases. In addition, it does not make much difference whether one has the oscillator operating above or below the ultrasonic frequency to which one is listening. Indeed, no oscillator is

## Conclusions

This article has been written to show the experimenter how he can use economical equipment for ultrasonic work. No attempt has been made to cover some of the more difficult aspects of the subject, such as voice modulation of ultrasonic waves for intercom systems or the measurement of distances by ultrasonic pulse techniques or the measurement of wind velocity. The aim has been rather to show what can be done easily by the use of simple circuits.

One can even use one of the circuits of Figures 3 to 5 inclusive to call a dog which has been trained to return to its master on hearing the ultrasonic tone, but it is advisable to use a relatively low frequency for this purpose (20 kHz to 25 kHz) to minimise air absorption and to use a frequency to which the dog is most sensitive. ●