Assembly Manual

VHF FM MONITOR RECEIVER

K-6000

DICK SMITH ELECTRONICS

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KIT

Need a spare VHF receiver for monitoring the local repeater? How about a dedicated unit for fox-hunting, or a radio direction finding receiver? If the answer to any of these question is yes, then this may be the project for you. A few hours of construction time is all it takes to build this little unit.

The heart of the receiver is a new integrated circuit from Motorola, the MC3362. Unlike many previous "single chip receivers" (such as the CA3089), this new integrated circuit provides all receiver functions from the antenna input to the audio preamp output. It is a low power dual conversion design with low power drain, excellent sensitivity, and good image rejection in narrow band voice and data link applications.

Dual conversion

A dual conversion receiver is an extension of the basic superheterodyne principle. A normal superhet has one local oscillator which is "heterodyned" or mixed with the incoming signal to produce an intermediate frequency which is then amplified and demodulated. This is referred to as single conversion and the intermediate frequency is typically at 10.7MHz for FM receivers or 455kHz (or 450kHz) for most AM receivers.

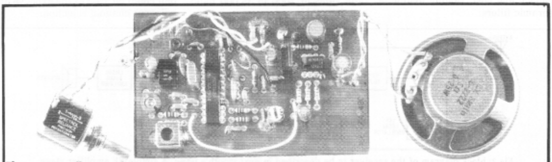
By contrast, a dual conversion receiver has two local oscillators. The first one beats with the incoming signal to produce an intermediate frequency (IF) of 10.7MHz. This is amplified in the first IF stage and then mixed with the second local oscillator which operates at 10.245MHz. This produces the second intermediate frequency of 455kHz (ie, 10.7MHz − 10.245MHz = 455kHz).

Dual conversion receivers with this arrangement are commonly used for narrow band FM reception. By "narrowband" we are referring to the fact that normal broadcast FM has a deviation of ± 75kHz and a total channel bandwidth of 150kHz. This is wideband FM.

For the amateur bands and commercial use, narrowband FM normally refers to a much smaller frequency deviation, such as ± 5kHz. This can vary though, for amateur operations, depending on which band is in use. This will be the subject of a future article.

Using the chip

Fig.1 shows a typical application of the MC3362 in a circuit from Motorola's application literature. It shows the incoming signal fed from



The parts are all mounted on a small double-side printed circuit board. Note that where the ground plane comes right up to the edge of a hole, the component lead must be soldered on both sides of the board.

the antenna via a matching network and .01μF capacitor to pin 1 of the MC3362. This is the input to the first mixer.

The first local oscillator can be run using a free running LC tank, or as a VCO using PLL (phase lock loop) synthesis. With variable tuning, a range of 4MHz is available using the internal varicap at pin 23. Alternatively, for single channel use, the local oscillator can be driven from an external crystal oscillator.

A buffered output of the first local oscillator is available at pin 20.

The Motorola data sheet says that the local oscillator can be run as high as 170MHz which means that, in this configuration, the highest receiver frequency we could cover would be around 160 MHz. As the chip itself was designed as a cordless telephone receiver for the US market (49MHz), the design lends itself immediately to either a 6-metre or a 2-metre receiver for amateur use.

A 10.7MHz crystal or ceramic filter connected between pins 17, 18 and 19 sets the bandwidth for the first IF stage where the signal is amplified before being fed to the second local oscillator.

The second local oscillator is a common base Colpitts type which is typically run at 10.245MHz under crystal control. A buffered output is available at pin 2. Pins 2 and 3 are interchangeable.

The mixers are double balanced to reduce spurious responses. The first and second mixers have conversion gains of 18dB and 22dB respectively and the mixer gain does not vary with changes in the supply voltage.

For both conversions, the mixer impedances and pin layout are designed to allow the user to employ low cost, readily available ceramic filters.

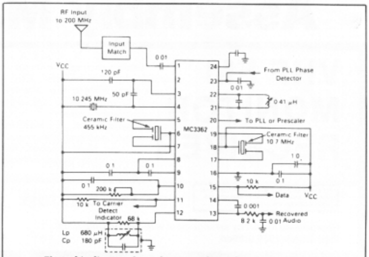


Fig.1: this diagram from the Motorola applications data shows how the MC3362 is used in a typical PLL frequency synthesised receiver.

Sensitivity is quite high. The input level for 20dB (S + N)/N is 0.7μV at 50MHz.

The 455kHz IF is filtered and fed to the limiter input, at pin 7. The limiter has a 10μV sensitivity for −3dB limiting, flat to 1MHz. The output of the limiter is internally connected to the quadrature detector which includes an internal quadrature capacitor.

A parallel LC tank is connected externally from pin 12 to Vcc. In addition, a 68kΩ shunt resistor is included which determines the peak separation of the quadrature detector. A smaller value will increase the spacing and linearity but decrease recovered audio output and sensitivity.

For data communications, the recovered audio output from pin 13 can be connected to an internal comparator between pins 14 and 15. FSK (frequency shift keyed) data rates of 2000 to 35,000 baud are detectable.

The hysteresis of the internal comparator can be varied by connecting a high value resistor from pin 14 to pin 15. Values below 120kΩ are not recommended as the input signal cannot overcome the hysteresis.

A meter drive circuit at pin 10 detects input signal level by monitoring the limiting of the limiter stages. It can be used to trip a carrier detect circuit, pin 11, at a particular input level.

Our receiver

Our receiver circuit uses a number of variations on the theme suggested by Motorola. The block diagram for the receiver is shown in Fig.2. It shows the main functions of the MC3362 which is preceded with a single BFR91 RF amplifier stage.

Our design uses a 10.7MHz crystal filter, although a ceramic unit could be used at the expense of adjacent channel rejection.

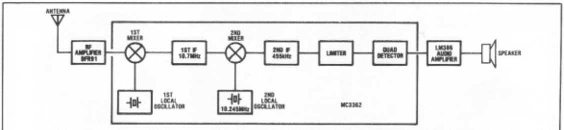


Fig.2: block diagram of the receiver to be described in next month's issue. A simple RF amplifier stage precedes the MC3362's input while the output drives a single-IC audio amplifier stage to provide loudspeaker volume.

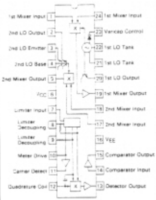


Fig.3: the MC3362 is virtually a complete narrowband FM receiver on a single chip.

Following the MC3362 we used an LM386 as an audio amplifier to provide sufficient drive to a small speaker.

We found that the receiver produced reasonable sensitivity without the suggested external BFR91 board-band amplifier. So this has been deleted as an unnecessary complication. As it stands, the receiver gives quite reasonable sensitivity (in the order of several microvolts).

An LM386 audio amplifier was used to produce adequate volume levels for normal listening conditions. The squelch is configured so that the DC output from pin 11 of the MC3362 is used to bias the audio amplifier off when no signal is being received. This also minimises the current drawn by the receiver when no signal is being received, an important point to consider if the receiver is to be run from batteries in a portable application.

Construction

The first prototype receiver was built on a single-sided PCB (using a ground plane on the component side) for additional stability. The board measures 102 x 63mm and is coded ZA1480.

Normal RF contruction techniques apply. Basically the most important thing is to keep component leads as short as possible. This means that all capacitors, resistors and transistors should be pushed down close to the board before soldering the leads.

Fig.5 shows the parts layout on the PCB. Begin construction by installing all the resistors, working down the parts list from R1 to R11. Bend the components leads against the copper side of the circuit board so that the components don't fall out of the PCB when it is turned upside down for soldering. Solder the resistor leads, then trim the excess lead lengths with a pair of side cutters.

After soldering the resistors, proceed to the capacitors, working through the parts list from C1 to C23. It is a good idea to cross the components off the parts list as they are installed, so that nothing is missed during construction.

Make sure that you install all the electrolytic capacitors with correct polarity. If you don't do this correctly, circuit damage can result.

For example, on one of the prototype receivers the 220μF capacitor was installed incorrectly. When powered up, the reverse voltage across the capacitor caused it to go short circuit. This caused pin 5 of IC2 to deliver about 6 volts DC (about half the available supply

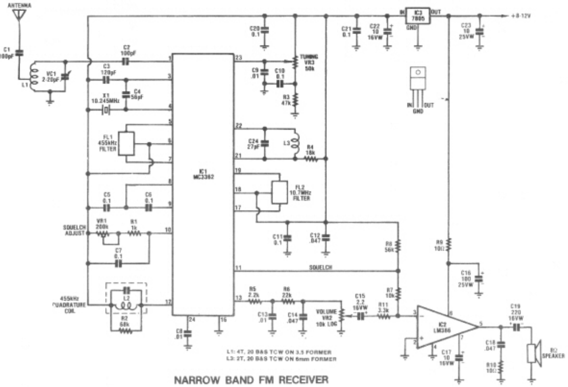


***Fig.4:* the circuit is based on the Motorola MC3362 (IC1) which is virtually a complete narrowband FM receiver on a single chip. L3 and C24 set the frequency band while the output (at pin 13) drives an LM386 audio amplifier (IC2).**

PARTS LIST

X1 — 10.245MHz crystal
FL1 — 455kHz ceramic filter
FL2 — 10.7MHz ceramic filter

Semiconductors
IC1 — MC3362 narrowband FM receiver
IC2 — LM386 audio amplifier
IC3 — 7805 +5V 3-terminal regulator

Inductors
L1 — 4 turns 25B&S tinned copper wire x 3.5mm dia.
L2 — 455kHz coil (from DSE L-2060 coil pack)
L3 — 2 turns 20B&S tinned copper wire x 6mm dia.

Capacitors
C1,C2 — 100pF ceramic
C3 — 120pF ceramic
C4 — 56pF ceramic
C5,C6,C7,C11,C20,C21 — 0.1μF monolithic
C8,C9 — .01μF ceramic
C10 — 0.1μF ceramic or metallised polyester
C12,C14,C18 — .047μF ceramic
C13 — .01μF ceramic or metallised polyester
C15 — 2.2μF 16VW electro
C16 — 100μF 25VW electro
C17 — 10μF tantalum
C22,C23 — 10μF 16VW electro
C19 — 220μF 16VW electro
C24 — 27pF (depends on frequency band)
VC1 — 2-20pF trimmer

Resistors

R1 — 1kΩ	R6 — 22kΩ
R2 — 68kΩ	R7 — 10kΩ
R3 — 47kΩ	R8 — 56kΩ
R4 — 18kΩ	R9,R10 — 10Ω
R5 — 2.2kΩ	R11 — 3.3kΩ

Potentiometers
VR1 — 200kΩ miniature trimpot, horizontal mount (squelch)
VR2 — 10kΩ miniature trimpot, horizontal mount (volume)
VR3 — 50kΩ multiturn potentiometer (tuning)

Miscellaneous
1 x PCB (code **ZA 1480**, 102 x 53mm), 1 x 8-ohm loudspeaker

voltage) to the speaker and consequently the IC blew its top.

Learn by our mistake — put the capacitors in the right way around.

At this stage the trimpots for squelch (VR1) and volume (VR2) can be installed, as can the two IF filters (10.7MHz and 455kHz) and the 10.245MHz crystal. Be careful not to use excessive heat when soldering the crystal, as the body of the crystal will be close to the tip of the soldering iron when soldering the leads.

The next step is to install the semiconductors. Ensure that the ICs are oriented correctly before you start soldering the pins. We do not recommend the use of IC sockets in the receiver as they can be unreliable. They also add stray capacitance and inductance to every IC pin and this can prejudice operation at very high frequencies (VHF).

So be careful to install the ICs correctly the first time — desoldering all those IC pins can be a pain and can render the ICs unusable.

Note that where component leads are connected to earth, they should be soldered on both sides of the PCB. This applies to the GND terminal of the 3-terminal regulator, pin 16 of IC1, pin 2 of IC2 and to quite a few of the resistors and capacitors.

The only components requiring any degree of preparation prior to installation on the PCB are the input coil L1 and the tank coil L3.

L1 is made by wiring four turns of 20 B&S tinned copper wire (TCW) or enamelled copper wire (ECW) on a 3.5mm former. After wiring, stretch the coil as shown in the photograph so that there is a 2mm, 3mm and 2mm gap between windings (see figure 6). The 100pF input capacitor (C1) is connected 1-1/2 turns from the C2 end of L1.

If using enamelled copper wire it will be necessary to scrape the enamel from both ends of the coil and pre-tin the leads prior to insertion into the circuit board.

L3 is made by winding two turns wire on 6mm former (see figure 7). Once again 20 B&S wire should be used although the gauge is no critical as we will be stretching the coil mechanically set up the frequency coverage required

The tuning control is a multi-turn 50kΩ potentiometer which is specified for ease of tuning. Because the tank circuit operates directly at VHF, the varicap tuning voltage is quite sensitive to adjust. Note that any drift of the tank frequency with temperature will cause a change in operating frequency. This can only be compensated for by changing the tuning voltage, via the tuning control.

In fact, to tune over the entire 2-metre amateur band requires a change of only 2V (from 2V to 4V) on pin 23 of IC1. And to change the tuning by 600kHz (the difference between input and output of a repeater) requires very little change in tuning volts. For this

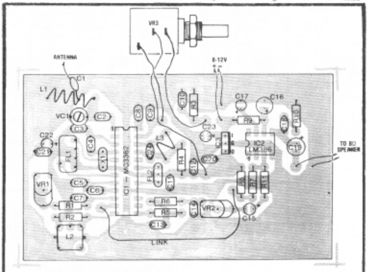
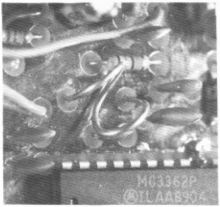


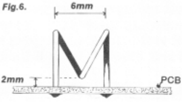
Fig.5: wire up the PCB as shown in this parts layout diagram. Keep all component leads as short as possible and don't forget to solder to both sides of the PCB where appropriates (note: ground plane not shown).



L3 is made by winding two turns of tinned copper wire on a 6mm former. The band of operation is set by squeezing or expanding L3.

The input coil L1 is made by winding four turns of tinned copper wire on a 3.5mm former. Note the location of the 100pF input capacitor (C1).

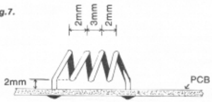
Fig.6.



L3 = 2 Turns, 20 B&S TCW on 6mm (15/64")

20 B&S = 1mm dia.

Fig.7.



L1 = 4 Turns, 20 B&S TCW on 3.5mm (9/64") Former

TCW = Tinned Copper Wire

reason a standard single-turn pot is not practical — you must use a multi-turn control.

The tuning control itself should be located away from the circuit board, so that the capacitance of the user's hand when tuning the receiver does not affect the tank frequency. Because the tuning control carries only DC, ribbon cable can be used to connect it to the circuit board.

An alternative would be to crystal lock the receiver by using an external overtone oscillator fed to pins 21 & 22. Motorola mention in their data sheet that a level of around 100mV is required for this style of operation.

Power up

Because the unit has its own 5V regulator, the receiver can be run from virtually any DC source over 7 volts or so. Normally this would be either a 9V or 12V battery, or a 9-12V power supply.

If you have a power supply with current limiting, it is wise to set the limit as low as possible to ensure that there are no unexpected fireworks when power is first applied. A correctly assembled receiver will draw less than 20mA from a 12V source.

Assuming that you have checked the component placement and found no errors, power may be applied. Check initially that the current drawn is not excessive and that the receiver generates white noise or "hash". You should also check that the squelch control (VR1) operates correctly; turning it anticlockwise should mute the receiver. Check the volume control trimpot (VR2) too; rotating it clockwise should cause an increase in audio level.

If a signal generator is available, it should be set to the desired frequency of operation and at a reasonable output level (say 100μV) to make identification of the signal reasonably easy. If no signal generator is available, connect a suitable VHF antenna to the receiver, so that the local VHF repeater or beacon can be utilised.

Once a suitable signal is available the receiver can be tuned by squeezing or expanding the tank coil to shorten or lengthen it. This varies the inductance and hence the tank resonant frequency. If you have access to a spectrum analyser, it is simple to check the actual tank frequency, which will be 10.7MHz above the desired input frequency.

This could also be checked by using a sniffer probe hooked up to a frequency meter. It may also be helpful at this stage to replace C24 with a 2-20pF trimmer to allow greater flexibility in setting the correct tuning range.

Once a signal has been located, peak L2 (the 455kHz quadrature coil) for maximum audio output. In fact, this can be done without any input signal — you simply adjust L2 for maximum receiver noise. The only other adjustment is to peak the VC1 input trimmer for maximum quieting using a suitable off-air signal.

Antennas

You will find that the receiver performs quite well with just a single piece of hookup wire connected to the input capacitor. The tap on the input coil ensures that a reasonably close match to 50 ohms is available if using a 2-metre antenna having coaxial feed.

Alternatively, a simple discone antenna will provide good results on a far wider range of frequencies. The frequency coverage of the receiver is not limited to the 2-metre amateur band and it can be successfully used on the VHF marine band, paging frequencies and VHF commercial frequencies.

Footnote

The purpose of presenting this project is to stimulate active experimentation on the amateur bands. Obviously, a receiver of this simplicity will not perform as well as a $1000 2-metre transceiver. However, it does show that reasonable performance is available at very modest cost.

Notes & Errata

Text and Illustrations courtesy of Silicon Chip