AN EXPERIMENTAL SHIRT-POCKET TV SET

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Early in 1964 an experimental television receiver was developed that was small enough to be carried in a shirt pocket. This was done in the Advanced Engineering Laboratories, at Motorola, as part of a general investigation into TV miniaturization. Because of the smallness of the picture it was not expected to generate significant interest. The contrary proved to be the case and this paper presents the design concepts and tradeoffs that were necessary.

Because this work was done before serious consideration was given to the use of integrated circuits for consumer applications, this set was built entirely with discrete components. If the receiver were to undergo re-design, integrated circuits would probably be used for part of the circuitry. These wouldn't necessarily result in a smaller set, but they might make it more susceptible to being mass-produced. As it is now, the unit is strictly an experimental design which is not presently practical for high-volume production.

Figure 1 illustrates the receiver. It does fit into a shirt pocket, although, admittedly, without much room to spare. The 1-1/8 inch picture looks out the top so that the picture may be seen while it is in the left shirt pocket.Also, it has built-in batteries and the earphone lead doubles as an antenna making reception possible while walking down the street.*

Going now to some statistics, the 29-transistor, 14-diode receiver weighs 12-1/2 ounces and occupies a total volume of 13 cubic inches. Only a single VHF channel can be received, although there were plans for a tiny, multiple-channel tuner which would have been squeezed in if the project had been continued.

Nearly half the space inside the set is taken up by the picture tube, which runs the length of the case. Most of the rest of the space is occupied by four alkaline penlight cells and the associated d-c to d-c converter power supply. Only a little over one cubic inch is taken up by the TV receiver circuits.

Figure 2 shows a view of the set while restint on a table. This is an off-the-air picture received from channel 5, Chicago It's not a very good photograph, but it couldn't be resisted because of the space-age subject matter.

*(If you think about this for a moment, and visualize millions of teen-agers viewing TV while walking (and maybe even while driving), you may conclude that it is a good thing this set isn't going into production).

Figure 3 gives an inside view. The electrostatically deflected picture tube measures about 4 inches long. As indicated before, the TV receiver circuits occupy very little space --- only 1.2 cubic inches. They are packaged in a three-layer module having a total height of about 3/4-inch. Each layer, or deck, is thus only 1/4 inch thick. The bottom deck, which has parts open to view, contains the deflection and sync stages.

The d-c to d-c converter power supply is located between the penlight cells and the just discussed TV module. It's a little larger than the TV module, with a large part of its space accounted for by the converter transformer.

Figure 4 is a close-up view of the bottom layer of the TV circuit module,to give some idea of how tightly packaged the parts are. Transistors in modified TO-18 metal cases were used, since the required types weren't then available in the smaller plastic packages as they are now.

Figure 5 shows a breakdown of some of the parts used in the set. Many of these are standard, off-the-shelf items, such as the small ceramic bypass which is used in transistor radios. There are some tantalums, which, though not so standard are real space savers. Most of the resistors used in the set are 1/10 watt units. The controls are of the hearing-aid type. Unfortunately, these are not inexpensive due to difficulties of manufacture.

Also illustrated is a pair of 1-inch diameter cores for the d-c to d-c converter transformer.

Figure 6 is the d-c to d-c converter circuit. It converts the 5 volts or so from the 4 penlight cells to 11 volts, 100 volts, 275 volts, 1200 volts and 3000 volts. The many outputs were made available to avoid having to use power-wasting voltage dropping and dividing resistors.

To minimize the number of secondary turns required, and thus keep the size of the converter transformer down, its output was multiplied by stacked, voltage-doubler circuits. Note that each higher output builds on the next lower one until the highest potential of 3000 volts is reached. Thus, the 1200 volt output is taken from a voltage doubler which, instead of being grounded, is returned to the +275 volt rectifier output. The 3000 volt output, in turn, is derived from a voltage quadrupler stacked on top of the 1200 volt output.

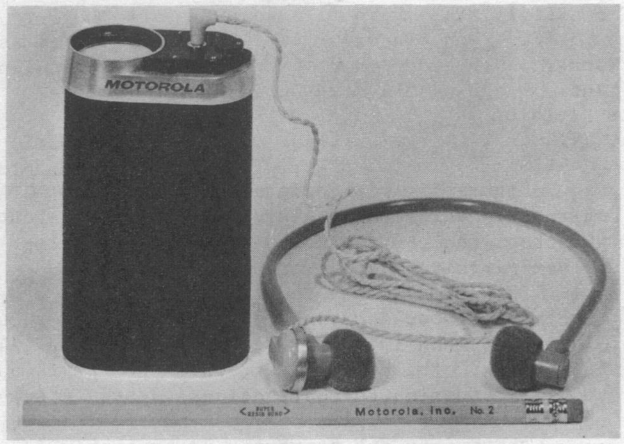

Figure 1—Shirt-Pocket TV Receiver, With Earphones.

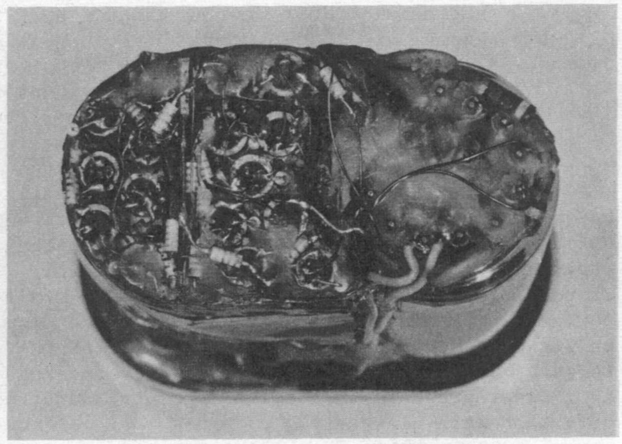

Figure 4—Close-up View of Bottom Layer of TV Circuit Module.

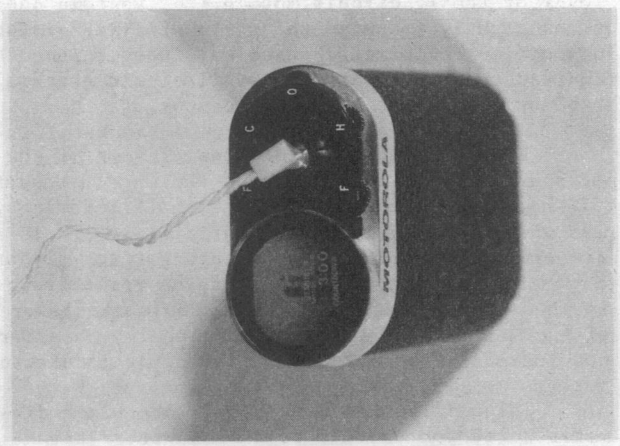

Figure 2—Receiver in Operation.

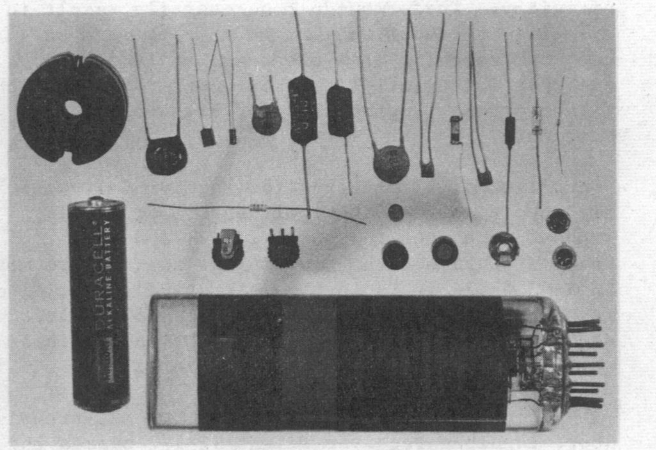

Figure 5—Component Parts Used in the Receiver.

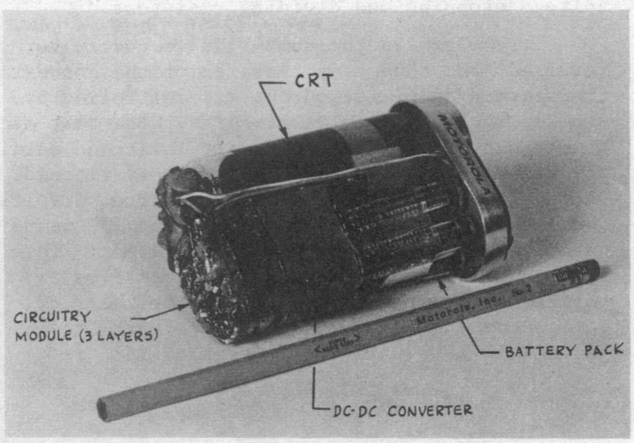

Figure 3—Receiver With Case Removed.

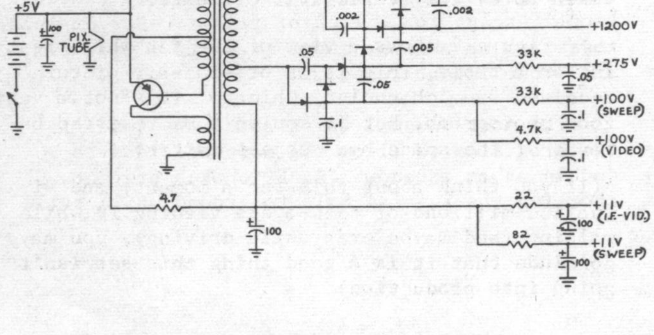

Figure 6—DC-DC Converter Circuitry.

Note that no rectifiers are needed for the +11 volt output, since the basic converter circuit is a self-rectifying type using the switching transistors in the additional role of low-voltage rectification.

Normally, this particular basic converter circuit is a reliable starter since the load is taken from the base winding. The rest is derived from a separate high voltage winding. The starting trouble initially experienced was relieved by being extra miserly with the various high voltage output loads and, also, by adding a small, unbypassed resistor in series with the 11 volt output.

The capacitor across the primary cells is to extend battery life. It smooths out the otherwise high ripple current which mercury cells didn't seem to live very long with. The capacitor's effect on alkaline cells wasn't determined because, up until a short time ago, only mercury cells were used. We changed to alkalines after learning that they have been improved since the set was constructed over two years ago.

Probably the biggest problem experienced with the d-c to d-c converter was interference generated by switching transients. This can be compared to car-radio vibrator hash and was very difficult to suppress, especially in a space-limited application like this one. It was, however, found that interference could be virtually eliminated by carefully positioning the converter module to a critical point along the length of the picture tube where interference was cancelled. Unfortunately, this "null" point was in the position intended for the batteries, so this fix wasn't used. A compromise solution was employed instead, which was to raise the converter frequency closer to the horizontal frequency so that the interference, though still present, was not objectionable. This solution was used with reluctance, since operating at the higher frequency reduced efficiency.

One of the original objectives was to have receiver sensitivity comparable to conventional portable TV sets. This requirement dictated the use of a full complement of stages in the signal chain; that is, r.f. amplifier, mixer, three i.f. stages, and a two-stage video amplifier.

Figure 7 shows the first part of this chain, the single-channel tuner. It is fairly conventional except for a lack of frills. For example, there are no antenna input traps to reject f.m. and other interferences.

The most unusual thing about the tuner is the provision to allow the earphone lead to double as an antenna. R. F. chokes prevent shorting the r.f. signals to ground while still permitting the audio signal to pass to the earphones. The .002 capacitor couples r.f. signals picked up by the 'phone leads to the input coils, while blocking the d.c. audio supply voltage.

The r.f. stage emitter was grounded directly to eliminate components and to improve the a.g.c. figure of merit, which would be degraded by emitter degeneration. A bad feature of this practice, though, is that temperature stability is compromised, and, also, the d-c operating characteristics of the r.f. amplifier transistor must be closely matched with the other a.g.c. controlled stages.

Figure 8 is the circuit diagram of the i.f., a.g.c., and first video stages. Unlike the mixer output coil, the relatively broad interstage coils are fixed-tuned to save space. Here in the i.f., as well as in the tuner, traps were avoided for compactness.

To conserve power, reverse a.g.c. is employed. This particular embodiment is an average a.g.c. system reminiscent of simple a.g.c. systems used in many TV sets during the early fifties, except that the controlled i.f. and r.f. stages are biased from the output of the first video stage rather than from the video detector, as they were in tube sets. The forward-biased subminiature diode reduces the d-c level without sacrificing loop gain.

Most of the circuits in the receiver are tolerant of battery voltage changes. The most significant exception was the first-video bias, which indirectly sets the a.g.c. bias to the controlled stages. This criticalness was solved by adding a simple regulator to supply a fixed voltage to the so-called a.g.c. control. With this innovation, the set will perform with battery voltages ranging from more than five volts down to about three volts.

Figure 9 shows the video output amplifier and picture tube. If the reader thinks that a decimal point was omitted from the video collector load resistor value, be assured it wasn't. It actually is a 47K. If it was a 4.7K, which is more typical, the video amplifier would consume more power than all the rest of the circuits put together. To prove this, assume that half the 100 volt video supply is dropped across the load resistor and the other half across the transistor. That would make the d.c. collector current approximately 10 milliamps, which, at 100 volts, would be one watt. With the 47K value, the video circuit takes only 1/10 watt. There are several reasons why such a high value is permissible in this application. First, extremely short leads and small components cut down capacity to ground. Second, the small-size picture permits a greater sacrifice in

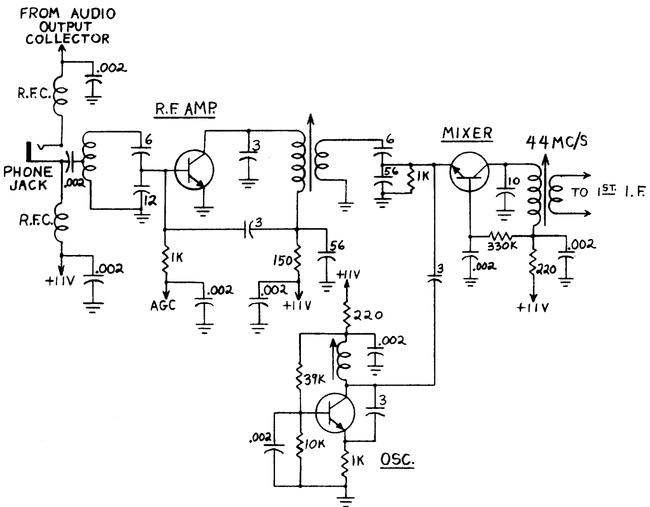

Figure 7—Tuner Circuit.

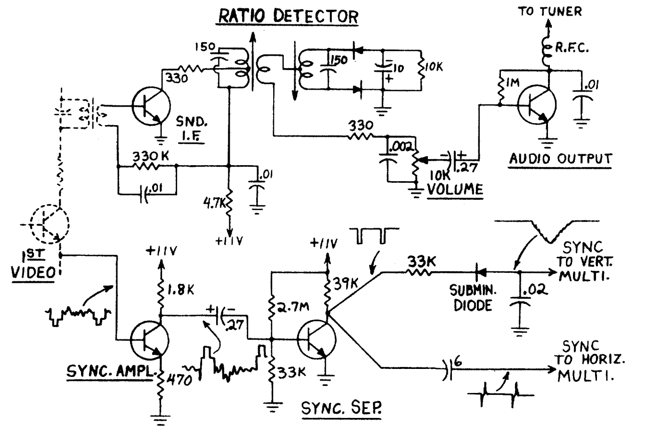

Figure 10—Sync and Sound Circuits.

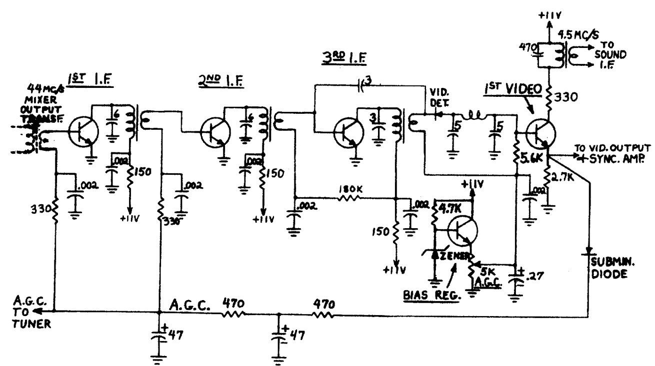

Figure 8—IF, AGC, and First Video Circuits.

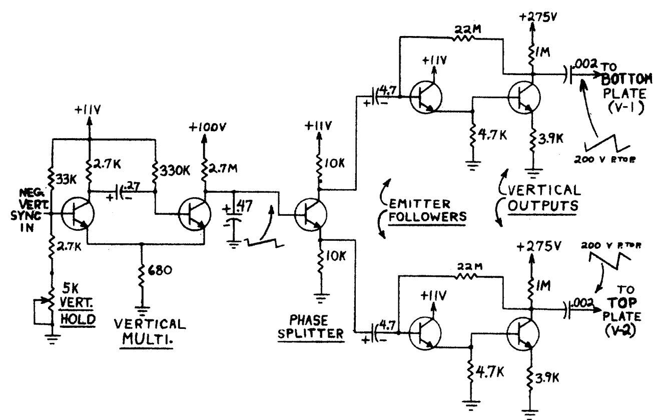

Figure 11—Vertical Deflection Circuit.

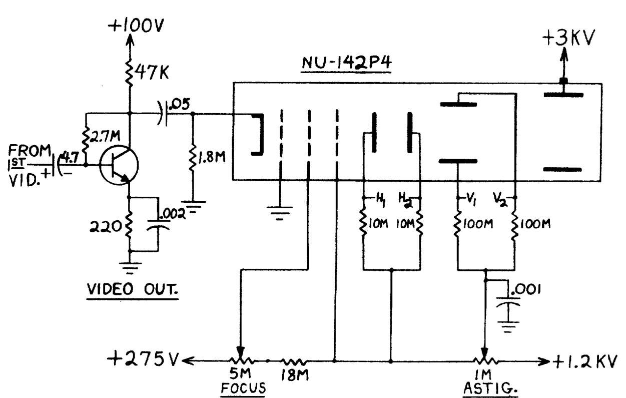

Figure 9—Video Output and CRT Circuits.

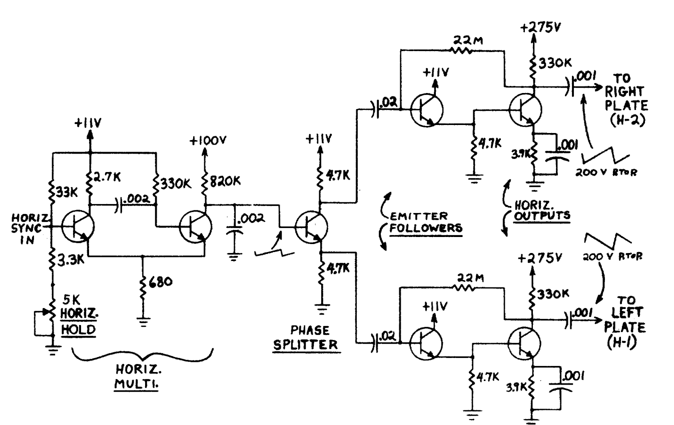

Figure 12—Horizontal Sweep Circuit.

high-frequency response than is possible with a large picture. Third, a fairly generous amount of emitter peaking is employed. Fourth, the i.f. response is "round topped" to peak mid frequencies, which introduces overshoots to compensate for smear caused by the video amplifier.

The picture tube is an electrostatically deflected type made for instrument applications. It normally is supplied with a green phosphor, but the vendor obligingly manufactured some white ones for this application. An interesting property of this tube, which is probably related to post deflection acceleration, is that the picture size stays approximately constant with large changes in battery voltage. This is one of the things that contribute to the set's ability to produce satisfactory pictures from above 5 volts down to as low as 3 volts. Another item is that, even though the picture tube heater is intended for 6-volt operation, it also functions satisfactorily down to the 3 volt minimum. An attractive point about this is that it takes less power at the lower voltages. Incidentally, with such a wide-ranging battery voltage, it is obvious that input power varies considerably. However, an average power figure may be calculated by taking a number of power readings at regularly spaced intervals throughout the useful life of the battery. If this is done, the average power comes out to about 1-1/2 watts.

The picture tube is self-biased with a 1.8 megohm cathode resistor. This provides some degree of beam regulation to stabilize high voltage loading, so as to minimize focus changes without having to stiffen the focus bleeder network. A practical design would probably have the 1.8 megohm value adjustable to accommodate tubes having different cut-off characteristics. Total nominal cathode current is around 15 microamps, with less than half reaching the post deflection accelerating electrode.

Another place where it may look like decimal points are missing, are in the values for the 100 megohm vertical deflection plate resistors. Such high values allow the use of relatively small coupling capacitors without excessively deteriorating linearity. (Vertical linearity is estimated to be ±3% of height, or better.) Recall that the large coupling capacitors in the 7-inch TV sets made around 1948 were about as big as this whole set. It should be noted that with such high value resistances, very little leakage can be tolerated in the coupling capacitors or the picture will be de-centered off the screen.

Speaking of centering, the few picture tubes purchased for this project had accurate enough gun alignments to obviate the need for centering controls. Whether this would hold true for production quantities is problematical, of course.

No spot-size measurement was attempted on this tube, but some idea of its capability may be ascertained from the observation that, with fresh batteries and precisely adjusted astigmatism and focus controls, it is possible to see scanning lines in a picture.

Figure 10 shows the sync and sound circuits. The ratio detector uses a double-tuned transformer extending across the middle deck in such a way that the primary and secondary slugs are accessible through holes in opposite sides of the module. Satisfactory Q was achieved for this and other coils by using copper for the module walls, instead of materials having poorer electrical conductivity.

A single audio amplifier suffices for driving the earphones. The .01 capacitor provides f.m. de-emphasis, as well as forming part of an r.f. decoupling network to prevent feedback due to the earphone lead doubling as an antenna.

The sync circuits are conventional, except that the horizontal oscillator is directly triggered instead of being controlled by a phase-locked loop.

Figure 11 is the vertical deflection circuit, which is nearly identical to the horizontal sweep circuit, except for part values. They both use emitter-coupled multivibrators with sawtooth outputs feeding phase splitters which develop opposite polarity signals for the push-pull output stages.

Figure 12 is the horizontal sweep circuit which delivers 200 volt sawtooth signals to the deflection plates. It should be noticed that the vertical and horizontal outputs are shown to be equal, despite television's unequal aspect ratio. This is because the horizontal plates, being closer to the beam source, have approximately 4/3 more deflection sensitivity than the vertical plates.

To conserve power, the output collector loads are made as high as possible. To do this in the horizontal circuit, without causing excessive retrace time, required the addition of .001 emitter peaking capacitors across the emitter resistors.

To conclude this paper, it might be appropriate to discuss means by which a set like this might be made more practical.

First of all, battery life is too short. Even with intermittent use, whereby the batteries get lots of time to recover, it is not possible to squeeze more than a few hours from a set of alkaline cells. This could be helped some by going to a very low power heater for the picture tube to bring the set's average power down to a watt. In addition, if the set were made just a trifle larger, it would be possible to replace the 4 penlight cells with a single, size-D nickel-cadmium rechargable cell. This could be recharged nightly for several hours use each day. If a single cell were used, it would be necessary to modify the d-c to d-c converter. It would also be desirable to change the picture tube heater voltage requirement to a single cell's output in order to avoid having it powered through the converter, with resultant loss of efficiency.

Getting a little more far-out or futuristic, what a pocket TV set this size really needs is a new kind of display device which would produce a picture covering the entire front of the set, instead of just peeking out the end like this one does. It is understood that there are people working on this kind of display in the Industry; let's hope they come up with something before we're all retired.

Acknowledgement is made for the help given by the following people on this project: Neil Frihart, my boss, for his encouragement and suggestions; Frank Hilbert, for suggesting the basic d-c to d-c converter circuit; and Joe Nelson and Orville Thurnell for their work on the exterior styling.