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Right Fancy CPO

A keyer from My Kid Brother.

The CPO, a/k/a code practice oscillator, has been a part of amateur radio for quite a long time now. I have no idea when the first one was built, or who built it for that matter. The fact remains, however, that the "code practice oscillator/CPO" has remained much the same since its inception.

The main — the only — purpose of the code oscillator is to provide a means of keyed on-off tones. Once CW is well mastered, the CPO is really of no further use!

CW comes in two parts: transmitting, and receiving!

Learning to receive is only half of the CW-learning experience. We are told that a dash is three times longer than a dot. The time interval between a dot and a dot (or a dash and a dash) for the letter "I" (or "M") is equal in time value to the length of a dot.

OK! Fair enough! So how do you measure that length of time? If you hold a dot for a given length of time, how do you know that you are holding the dot long enough? How do you know, for that matter, that the dash you send next is three times longer than the dot? Or too short maybe? Or even too long?

While learning to send CW in preparation for my Novice test, it occurred to me one day that learning to send CW has a lot in common with learning to play music — and the playing of music is a motor skill. CW sending, also like music playing, is a "motor skill," too. It uses only one tone, so unlike with music, you don't have the dimension of "pitch" to deal with. However, as with playing music, you are dealing with sensing time (musicians call it a time feel)!

Developing a time feel in playing music is facilitated by practicing with a metronome, and practicing for an incredible amount of time (more than you want to know)! While I was working one day with a metronome, it became obvious to me that a note had to be held accurately for a given interval of time in music, in much the same way (in CW) that dots and dashes have to be "time accurate."

There are many different length-of-time notes in music, but only two different "note lengths" in CW — the dot and the dash (the verbal use of dit and dah bear witness to that fact). Well, you can't very well adapt a metronome to help in learning the sending of CW. However, playing a musical instrument, such as the bass fiddle, is a motor skill. Sending, the playing of, CW, is a motor skill also (although nowhere near as involved as playing the bass fiddle).

So the techniques that I used in learning to play music, modified, will work for the learning of CW "playing." This CPO, I believe, fills a void in learning CW that has been there all along — that is, until now.

Back when I was in high school, a fellow student, David T. Holmes Jr. W8UMP, was two years ahead of me and had his General class license. He became my friend and amateur radio mentor. Dave volunteered his time, expertise, and patience (if you're out there Dave, thanks!) to teach me the necessary code and theory in order for me to pass my Novice test.

One day, while struggling with the code, it occurred to me to handle the task the same way as though I were learning to play a new piece of music, as already mentioned. Just practice the sending of CW the same way. Practicing, being patient, and persevering are also key ingredients in learning to play music. Remember, this CPO is for learning how to transmit CW. I know that there are those out there who have learned to receive the entire CW alphabet, numbers and punctuation, in under 150 microseconds — nice going! Transmitting CW, the other half of the CW communicating system, however, is another story.

Over the years, every now and then, memories of my Novice license preparation days come back to me —

particularly when I hear amateurs say that "musicians have the edge when it comes, to learning CW." If they do, I believe I can take the mystery out of it. The "edge" can be summarized by these three words: practice, patience, perseverance!

There, is a "rhythm to the code," it is said. In a manner of speaking , rhythm could be likened to the mirror image of timing: a time feel, which is akin to rhythm. The metronome is a mechanical device that could be thought of as a "time mark generator" used by musicians. It generates clicks (or pulses), signals if you will. The pulses/clicks are used to help in the development of a sense of rhythm because they occur on an accurate, regular basis.

A time sense, or time feel, is very important in playing music. It is equally important in sending CW. In music, some notes are long, (just as there is slow CW), and some notes are short — for instance, CW sent at 50 words per minute or more has a lot of short notes! So how much of a difference is there between a long note (dash) and a short note (dot), at any given speed? How do you learn to send/play the particular CW (dot, dash)character/note for the correct length of time, initially, and consistently thereafter?

Music teachers say that "a quarter note gets one pulse" (some teachers also say beat instead of pulse). What this means is that you start a note, and you hold that note for a measured interval of time, and you release. When practicing with the metronome, you start the note simultaneously with the first click, and hold the note till the second click occurs, and simultaneously release the note with the second click (golly, that's a lot like sending a dot in CW, isn't it?). Start the note with the first pulse, hold it, and release with the second pulse! Simple, isn't it? That note (time interval value–wise) is a quarter note. A half note is twice as long as a quarter note. You start the note with the first click of the metronome, and hold it till the second click occurs, and continue to hold it till the third click occurs, and simultaneously release (see the timing diagram). The note that is held twice as long as the quarter note is called a half note. A half note is twice as long as a quarter note.

"OK, so how do I get a dash out of all of this?" you say. Well, note time lengths can be combined, or linked (musicians say tied). IF you start with the first metronome pulse, hold it for the second pulse, continue to hold though, and release with the fourth pulse, you have a quarter note "tied" to a half note (in music it would be indicated as a half note with a dot beside it). If you link quarter and half notes, and analyze by counting clicks (without any separation), it adds up, clickwise, to four counts the time length of a dash.

There it is, analyzed. A dot, and a dash, which is three time intervals longer than a dot (notice the time indicators on the timing diagram). You can get a better understanding of what this is all about, with your fingers. Place your hand palm-down on the table, fingers spread. The fingers, represent clicks, the space between the fingers represents, "the 'on' time interval." The space between the index and second finger is the "interval" of a dot. You can animate a dot by tapping first the index finger, then the second finger (hum or whistle between taps). If you do that, you have a somewhat crude but accurate representation of a dot time length.

As was said, two clicks on a metronome result in a dot, time interval–wise. A dash is done in a similar manner, but notice that you need to add up the time interval spaces between the fingers. That turns out to be a "four count" on the fingers, or four pulses of a metronome. Start by tapping the first finger, and start humming and holding the hum until you tap the fourth finger — that's the length of a dash! This CPO transitions from the time marking aspect of a metronome to the generation of accurate-length-of-time tone intervals. Marking time, without time marks. Marking time-interval lengths by generating measured tones is what this fancy code oscillator does. When keyed, a tone stays on for a measured time interval. If you don't hold the key long enough, the dot/dash you send will end too soon. If you hold

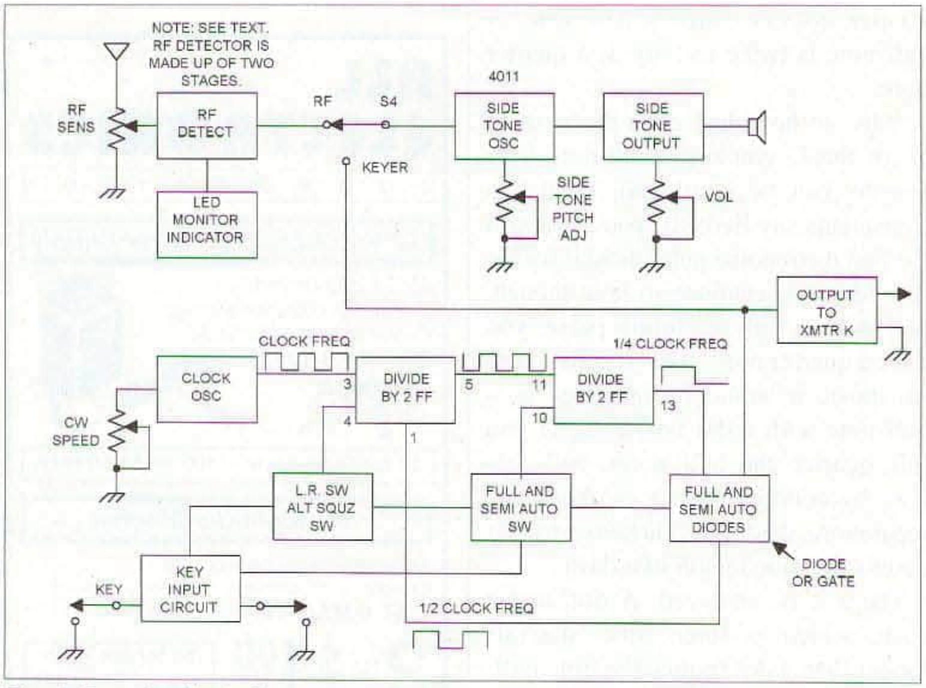

Fig. 1. Function block diagram.

the key too long, the dot/dash will end in the correct amount of time, and possibly the next dot/dash will start. You could say that this is dissecting CW, and looking at it under a microscope. I guess it is; however, this is done with the eventual goal of acquiring good CW sending technique. An important thing in operating CW, don't you think?. This code oscillator generates the tone between the "time mark" clicks, and in this way helps you develop a sense of CW rhythm.

This fancy code oscillator is more than just another "pretty face." For instance, it can be used for both full and semi-automatic keying. It has a provision for right-left-hand keying, squeeze/alternate keying. It also incorporates an RF keying monitor, with an LED indicator.

It can be used as a tutor to help in learning to use a "bug" or "straight key." The keying speed can be adjusted from below 5 wpm to over 50 wpm. It can key any transmitter. The right-/left-hand switch was added thanks to my old Air Force buddy Dan Coyle of Dayton, Ohio. Dan is a leftie. He pointed out that the original was for the exclusive use of right-handed folks, so a right-left switch was included.

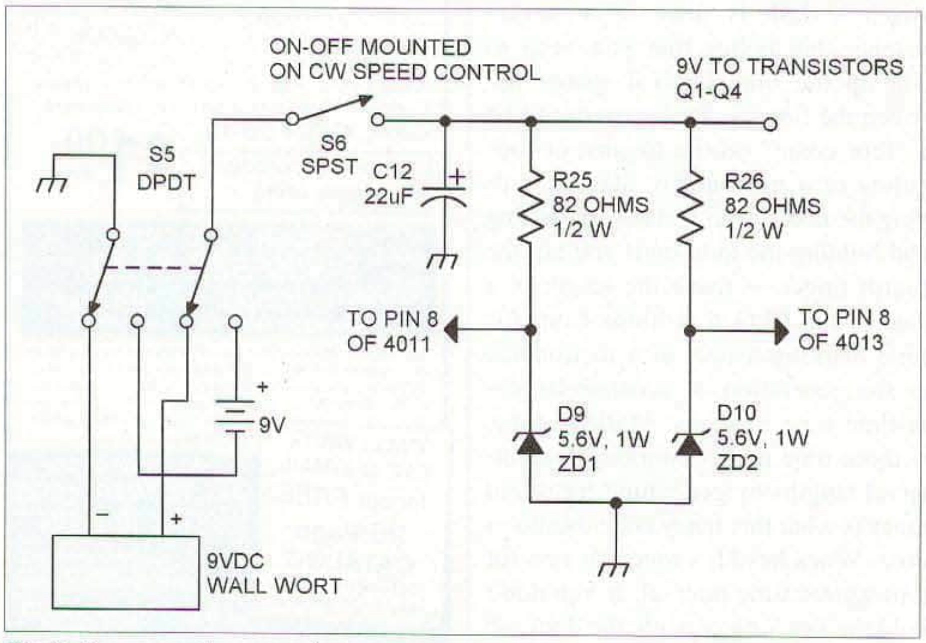

Fig. 2. Power supply connections.

Using this CPO "forces" you to be CW-honest! Because the dots and dashes are not self-completing, you can't speed up or slow down, or short-change the time length of either dot or dash. You send good CW. That's why this CW-transmitting-tutor is similar to a music teacher, insisting that you do it right, and scolding you for "playing those quarter notes too short," or "rushing the whole notes."

The bare-bones circuit of this device first appeared in the Tab Book entitled *New IC FET Principles and Projects*, by Sessions and Tuite, copyright 1972, as project 14, "Integrated-circuit Keyer," on pg. 124. In the early '90s, I did a revamp and used different ICs because it made it possible to obtain all the parts at Radio Shack. The revamp was published in *Radio Fun* magazine in the early nineties. Only two of the four sections of the 4011 were used for the clock oscillator. It seemed a waste not to use the two other sections for a sidetone oscillator. Well, once we have a dedicated sidetone oscillator, why not devise a way to use a straight key? The sidetone could then be used as an old-fashioned code practice oscillator. While using the unit, it became obvious that the straight key option could also be used as a transmitter tune function. Why stop with a straight key option — why not have the sidetone incorporated as part of an RF monitor as well?

One day, while reading the mail on two meters, I heard the lament that "it would be nice to have a Vibroplex bug, but it takes practice in order to learn how to use those things." Well with the tune provision, and an electronic (double) key such as a Nye or Bencher or similar, this CPO can function as an electronic bug. You have (electronics-generated) automatic dots on one side, and manual dashes on the other side. You can slow the speed to a comfortable rate, set the switch to the TUNE/SEMI AUTO position, and use this

CPO as a practice Vibroplex bug. Making the transition, then, to "the real thing," will be a lot easier.

Not only that, but the reverse is possible. The sidetone can be accessed, so that you can plug in the Vibroplex bug and you can practice, making for an easier electronic-to-the-real-thing bug transition. If you are completely new to amateur radio, plug in a straight, and the device can be used the same as an old-fashioned code oscillator. Included on the RF monitor side is an LED indicator. If you have a hearing defect — "are tone deaf" is how some describe it — the LED allows for visual CW. Other than egg in your beer, I can't think of anything else you can ask for.

How it works

Reference the schematic, block diagram, and signal flow diagram. The heart of the CPO is the clock oscillator portion of IC 4011. Its speed is adjusted by R12 in series with R13, and C8. R14 and R15 are also part of the circuit that makes up the user speed control adjustment. R15 is the front panel user control; R14 is an internal 20-turn trimmer speed limit-set pot. Refer to **Fig. 1**. 1/2 of the 4011 generates a signal which is fed to pin 3, 1/2 of the 4013 dual flip-flop (FF-A); the clock signal is divided by two by the first half of the 4013. The output, pin 1, of FF-A, is fed to the diode OR gate, the 1N914's. (See signal flow diagram also.)

The signal is impressed on point A (of the schematic as well as signal flow diagram), the base of Q6, which turns Q6 on and off. Q6 is the relay driver transistor (a 2N2222). Closing the dot key results in shorting pin 4 of FF-A to ground, resulting in the transmission of a dot. However, here's where things get more involved, with the operation of the second FF, and what contribution it makes.

The signal from the first half of the 4013 FF-A serves as a clock for the second half of the 4013. When the key is pressed on the dash side, pin 4 is shorted to ground and pin 10 of the 4013 is grounded through the diode D6. Closing either dot or dash key removes the pull-up voltage provided by R16 as well as R19 (in the schematic). The pull-up voltage is necessary to ensure that the 4013 is held OFF at pin 1 when the key is opened.

Also, in generating a dash, the output of the first half of the 4013 is pins 2, 5. The output at pins 2, 5 is the same divided-by-two clock signal that is output at pin 1, only it's inverted. The pins 2, 5 signal serves as a "clock" for the second half of the 4013 FF-B. Again, this "clock" signal is divided by two by the second F-F B (as in timing diag. C).

The output of the second 4013 FF-B is fed to the diode OR gate; however, unlike the generated "DOT" as described above, that's only two thirds of the DASH signal and there is no automatic output. There is no output, because a DASH can only be generated if both FF-A and FF-B are "turned on." FF-B is turned on by closing the dash key, shorting pin 4 of the 4013 to ground, which removes the pull-up voltage from pin 10 of FF-B. Both FF-A and FF-B are turned on by closing both keys at the same time, or through the inclusion of diode D6 in the schematic, and closing the DASH side of the key. Diode D6 can be switched in and out of the circuit by S2. This enables squeeze or alternate keying to be used.

In either case, the outputs of FF-A and FF-B are combined in the diode OR gate and produce a glorious

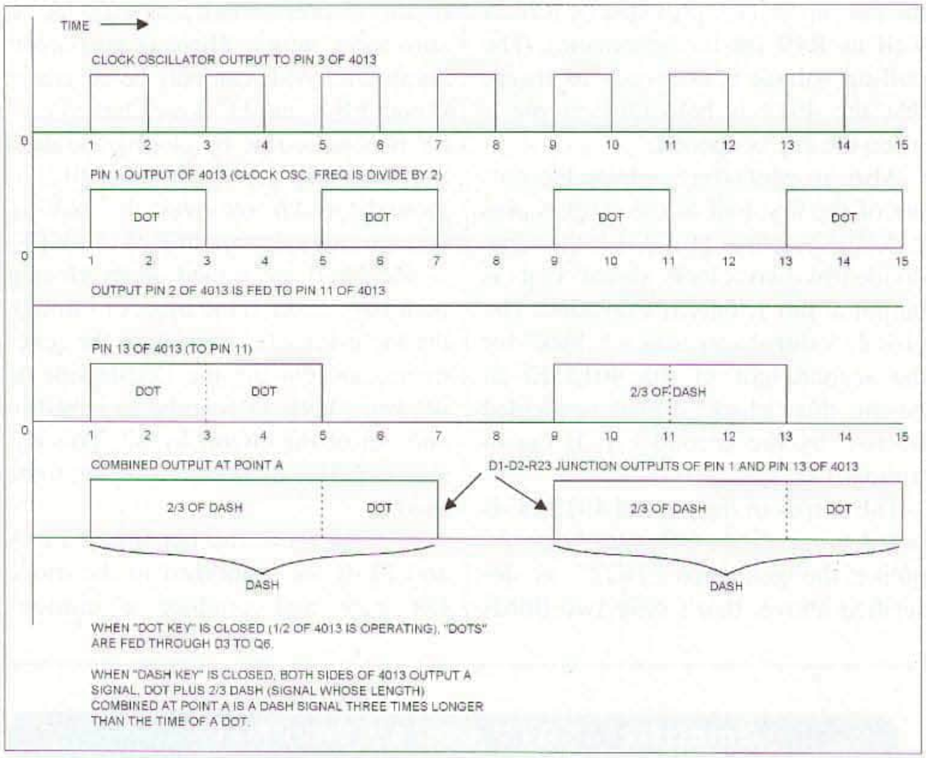

***Fig. 3.** Timing diagram.*

TRANSMITTED perfect dash! The upper part of **Fig. 1** shows a selectable (through S4) RF detector. It allows for using the sidetone oscillator while transmitting, or monitoring the signal transmitted by the transmitter, as part of the CPO (as you can see, this bad boy is more than just another "code oscillator"!) because it can provide an alternate means of monitoring a transmitted signal, other than the included sidetone generator.

The sidetone oscillator is made up of the other two of the four sections of the 4011. The clock and sidetone oscillator have exactly the same circuit configuration, except that the resistor and capacitor values are different. The sidetone pitch is adjustable; the nominal frequency is 750 Hz. The output of the side-tone oscillator is fed to the output transistor (speaker driver), direct-coupled. The sidetone output transistor is configured to "amplify" the square wave output of the sidetone oscillator. The transistor functions as a pulse amplifier — this configuration was chosen because it would operate well, with a minimum number of parts, at higher efficiency than a regular audio amplifier.

That's also the reason a transformer is used in the speaker drive circuit. The output transistor was required because of the lack of output level of the 4011. The on-off switch is mounted on the volume control. The keying relay K has a bypass (key click) capacitor across it. Relay K is an SPST reed relay; this particular unit is available at Radio Shack. Another reed relay could be used; however, the relay winding must be able to handle the collector current of Q6.

C10 and D5 make up a relay driver decoupling circuit. Q5 allows for direct keying during semi-automatic operation. When the key is closed, the forward bias is removed from Q5; the output goes high and the signal is fed through steering diode D7 through switch to the base of Q6 through current limiting resistor 23. D8 and C11 form a power supply decoupling circuit.

The power supply

The project started out using a single 9V battery. However, adding the sidetone oscillator made it absolutely necessary to design into the unit decoupling provisions for the V+ pins of the ICs. Without the parts used in the de-coupling network, specifically the zener diodes, really bad feedback occurs through the power supply. (See power supply.)

Without the zener diode circuit, the device operates like anything but a keyer. I initially tried the old standby, a resistor/capacitor de-coupling network, which proved to be woefully inadequate. One watt 5.1 volt 1 watt zeners are used; 1/2 watt zener diodes proved to be too small — they could not handle the current swing — but the larger-wattage zeners draw much more current. The circuit and components shown in **Fig. 2** worked and were incorporated.

The device, overall, draws more current than I would like. Unfortunately, a single 9V battery will not last too long (three or four 9 volt batteries could be connected in parallel for longer operating time). AA or larger-size cells, six of them wired in series, are a good choice. Six C cells in series would be a good choice, too. They have a good energy-density to size ratio; however, they are large compared to AAs, but they do last considerably longer than AA cells. An AC battery switch is provided for batteries or a 9-volt "wall wart" power pack operation. A good, filtered, DC wall wart (about 800 mA) should do it.

How do we use this thing?

To start, set the switches for full automatic, and internal sidetone. Use any full automatic key. For that matter, you can probably make some sort of key lash-up using microswitches, if you have no key — or even two brass strips wired to act as dot dash keys will get you started. Set the right-/left-hand switch to send either dots or dashes when the "finger presses" that side of the key. In other words, you want to use the full automatic key as a single straight key one half at a time to have immediate access to either dot or dash control. Set the unit so that the fingers side is used in sending dots. The thumb controls dash transmission. A straight key alone can be used; however, a stereo plug must be incorporated and wired appropriately, and then you have to switch the right-left switch back and forth for the appropriate dot or dash side.

Here is the meat and potatoes of this CW smorgasbord.

1. Start at a slow speed and do dots only — a few mistakes are acceptable — and *practice!* Stick with sending dots until you feel as though you could stay with the machine forever. How long this takes depends on the individual; everybody is different.

2. Then slow down the speed a little, and stay with the machine, etc.

3. Next, slow down a bit more. The reason to slow is to burn in a TIME INTERVAL FEELING! Remember, we are looking at dissected CW under a microscope.

4. Finally, the day arrives when you are ready to pick up speed. Increase your speed to something comfortable, where you just, just, start making mistakes; then practice some more.

5. Return to the slower speeds and practice slow-speed CW to retain what you established in the first four steps.

When you have that down, practice the dash next, the same way, and following steps 1 through 5. Warm up each day by starting at the slower speeds. When you have mastered the above for I and T, you have established a CW foundation. Next combine dot dash, or dash dot, it doesn't matter which, and practice A or N at a comfortable speed and, of course, follow steps 1 through 5, and that's the basic routine. Follow with the letters M, I, S, O, etc.

Keep in mind, and it's important enough to warrant repeating, that we're working to develop a timing sense. I guess it could be called CW rhythm. As stated before, it takes practice, perseverance, and patience.

The patience, for most, is to have patience with yourself. Boredom is for children. Talk about boring, if I had a nickel for every time I practiced a major scale, I'd be as rich as Bill Gates; well, maybe not quite. Once you have

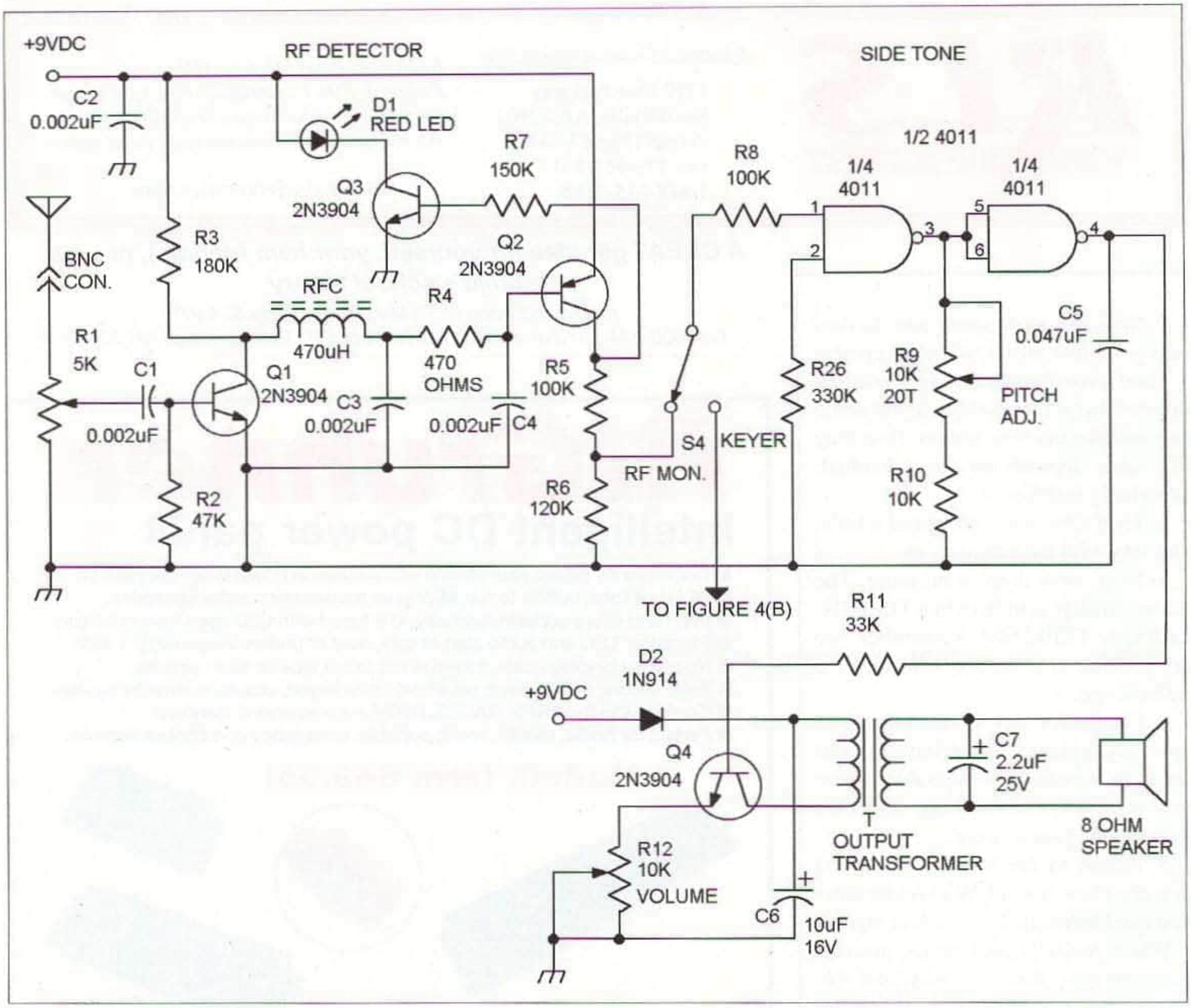

Fig. 4(a). Main schematic.

played a major scale there is nothing more to learn, intellectually; however, practicing scales on any musical instrument is vital if you want to play well. Boring? Go to agony and turn left! As you persevere and see the positive effect on your performance, it gets easier overall. The motor skill learning period gets shorter, and your CW sending gets better, and the speed takes care of itself.

As for the "CW is useless" crowd, I don't care how many new high tech communications gadgets come on the scene, CW is like oars (oars have been around even longer than CW, I'll bet) that you take along in a "row boat" that has an outboard motor hung on its stern. Those oars (you do take them along, don't you?) just might come in handy if the motor conks out.

But, but, oars are so slow, so low tech. CW, like the oars, may come in handy at some point in time, too, even though you have the latest microprocessor-controlled boat motor.

The ops who like CW find CW handy anytime. I have for years been using the essence of the above outlined method, in order to learn to play what at the time were rather difficult passages in a musical composition. The method works for music. Sending CW is nowhere near as involved as playing music!! Be patient with yourself. Practice the above method on a regular basis. And persevere, "stay with it." Who knows, in time you might even get the urge to learn to play the bass fiddle — well, it worked the other way around for me!

Musicians have "the edge" in learning CW. There's nothing special that musicians have that makes it easy for them to learn CW — they just know how to practice! Playing music is a motor skill. "Playing" CW is a "motor skill," too, but much less involved, and orders of magnitude simpler than playing music.

Construction of this project is straightforward, for the most part. I used perfboard because I had the right-size piece on hand. I like using sockets for transistors as well as ICs on perfboard, or on a PC board. Component layout is in general, not critical. The only thing that I found to be critical is the RF monitor circuit layout. Originally I constructed the monitor on the main circuit board; that necessitated

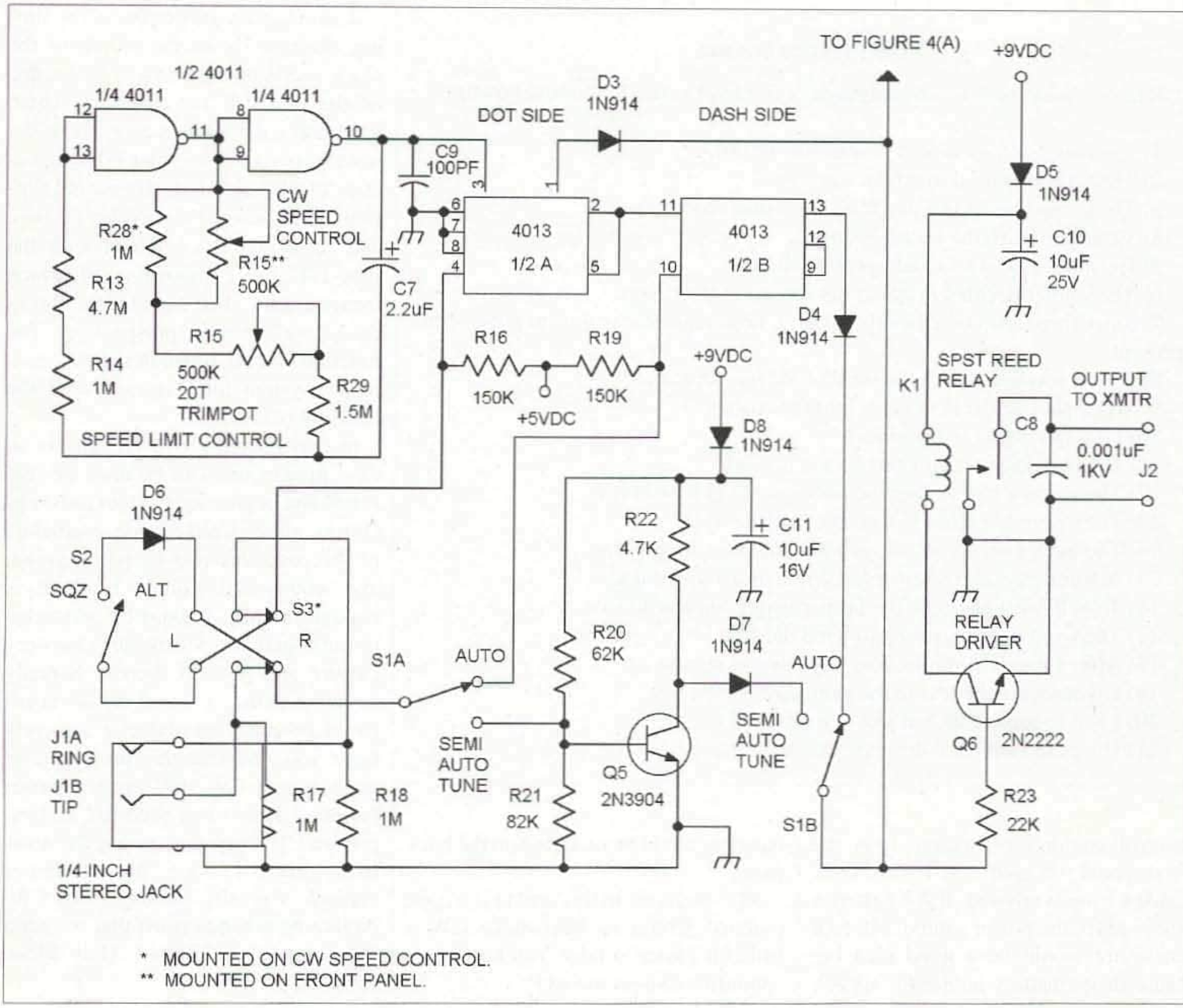

Fig. 4(b). Main schematic.

the component parts pieces to be too close. I found that there was stray electromagnetic coupling between transistors that rendered the detector circuit useless. However, the RF monitor circuit could be made close-spaced if proper shielding were used; also, that would make for a compact project. It's possible to build the RF monitor and sidetone circuit only, to be used as a standalone transmitter monitor. I found that the RF circuit transistors have to be separated at least one inch; otherwise, there is really bad, stray coupling. There is a serious interaction between transistors.

How the RF section works: An RF signal is fed from the pickup antenna through the RF sensitivity control, through C1, and is developed across R2. Q1 behaves as an RF detector, and its output is filtered through the inductor L along with C3, R4, and C4. The filter section components are what facilitate broadband operation, i.e., 1 MHz to about 50 MHz. Q2 is a level shift amplifier and supplies a DC signal to gate the 4011 sidetone oscillator portion through the resistor R8. The DC output from Q2 is fed directly to Q3 through current limiting resistor R7. R5 and R6 form a voltage divider, which reduces the DC gate voltage to a safe value for the sidetone gate input pin 1.

I used a Radio Shack project box to house this beastie, which measures 5-3/4 by 5-1/4 by 2-3/4. Any other metal project box could be used; I don't think I'd use an ABS plastic box, however. The layout for the most part is not critical, but it's best to keep the leads to the front panel controls as short and direct as possible.

The speaker, which I mounted on the front panel, could have been mounted on the side. Ventilation slots are cut into the cover, and it would not be necessary to cut a big hole in the front panel (isn't hindsight wonderful?). Not only that, it would also give more room to spread out the user controls. The back panel has the monitor pickup antenna connector (a BNC was used because it was lying on the workbench at the time) mounted on it, as well as the RF sensitivity control. Coaxial cable, in this instance, was not needed because of the short leads involved. There's no reason why the RF sensitivity

CW Practice Lesson

Reasons Why the English Language is Hard to Learn (Author unknown)

1) The bandage was wound around the wound.
2) The farm was used to produce produce.
3) The dump was so full that it had to refuse more refuse.
4) We must polish the Polish furniture.
5) He could lead if he would get the lead out.
6) The soldier decided to desert his dessert in the desert.
7) Since there is no time like the present, he thought it was time to present the present.
8) A bass was painted on the head of the bass drum.
9) When shot at, the dove dove into the bushes.
10) I did not object to the object.
11) The insurance was invalid for the invalid.
12) There was a row among the oarsmen about how to row.
13) They were too close to the door to close it.
14) The buck does funny things when the does are present.
15) A seamstress and a sewer fell down into a sewer line.
16) To help with planting, the farmer taught his sow to sow.
17) The wind was too strong to wind the sail.
18) After a number of injections my jaw got number.
19) Upon seeing the tear in the painting I shed a tear.
20) I had to subject the subject to a series of tests.
21) How can I intimate this to my most intimate friend?

control couldn't be mounted on the front panel. Of course, if it was, coax cable wiring is advised. If AA batteries are used for the power source, a deeper enclosure would be a good idea because then a battery holder for six AA batteries could be mounted on the back panel.

Also included in this article is a code practice lesson to help make CW a little bit easier to take. You know that spoonful of sugar theory!!

A word about the graphics. The timing diagram shows the output of the clock oscillator and how it is divided by the first F-F, the output of which generates a dot straight away. How the inverter output of the first F-F behaves as a "clock" signal for the second flip-flop. The second F-F divides by two, and its signal is combined with the first F-F, the combination of which forms a dash. The signal flow shows this from another prospective. The function block illustrates how each major system interconnects, and the function of each.

In conclusion, all in all, this is an easy project that can be used by seasoned and beginning amateur radio operators alike. Unlike code oscillators of the past, this one keeps on going, and going and going! If there is enough interest, I could be persuaded to put together a kit of parts sans enclosure and pots. If there is a really strong demand, a wired circuit board could be made available. I sincerely hope you find that this project helps your overall CW skill in the manner intended. Here's to a good fist, and improved CW operating among the amateur ranks. I hope this generates enough curiosity among the CW-oughta-be-a-band crowd that we get a few converts. 73 and God bless, K8MKB.

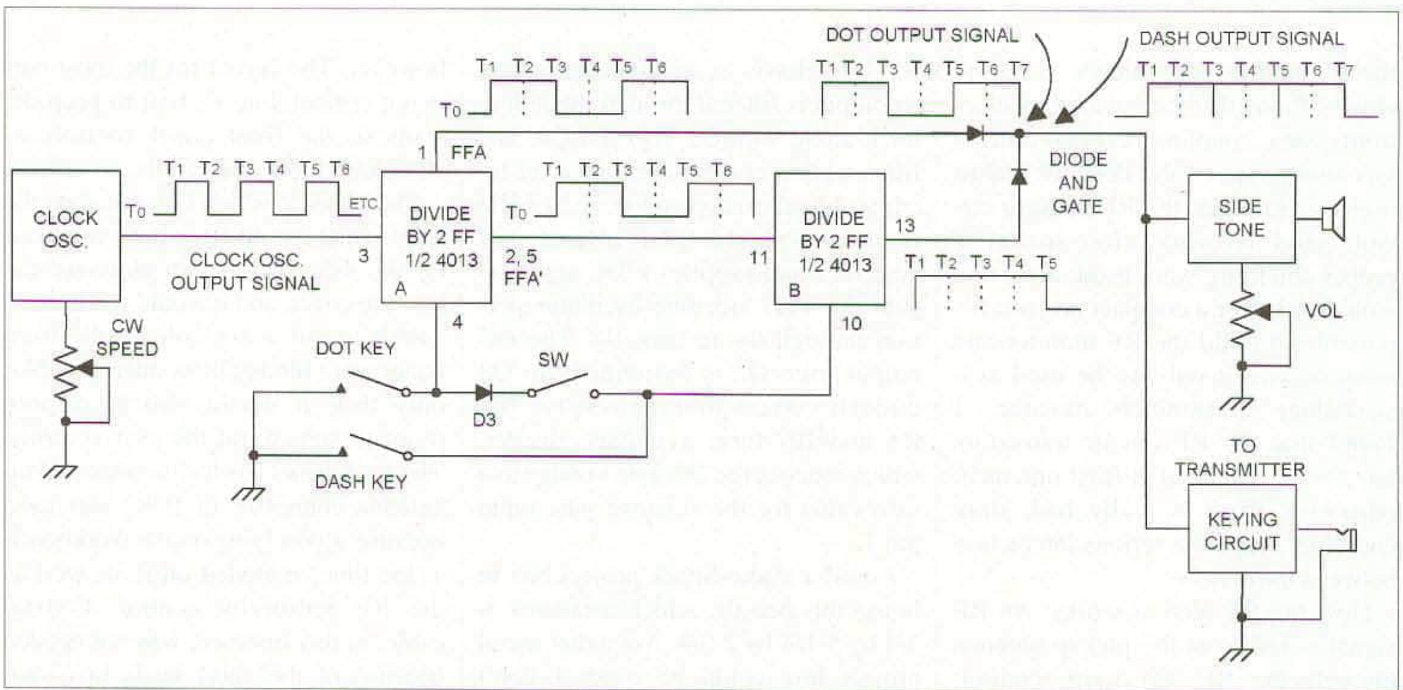

Fig. 5. Signal flow diagram.

Part	Description	Part	Description
R1	5k 1/2W pot	C1–C4	0.002 µF
R2	47k	C5	0.047 µF
R3	180k	C6, C10, C11	10 µF electro
R4	470Ω	C7	2.2 µF axial electro
R5, R8	100k	C8	0.001 µF 1 kV ceramic disc
R6	120k	C9	100 pF 50 V ceramic disc
R7, R16, R19	150k	C12	22 µF radial electro
R9	10k 20T trimmer, top adjust	D1	Red LED
R10	10k	D2–D8	1N914
R11	33k	D9, D10	5.6 V 1/2W zener
R12	10k 1/2W audio taper pot, with SPST	Q1, Q3, Q4, Q5	2N3904
R13	4.7M	Q2	2N3905
R14, R17, R18, R28	1M	Q6	2N2222
R15	500k 1/2W linear taper panel mt. pot	IC1	4011 (osc. timing/clock) quad two-input NAND gate
R20	62k 2%	IC2	4013 F.F.
R21	82k	J1	1/4-inch stereo type
R22	4.7k	J2	1/4-inch single circuit type
R23	22k	S1, S3, S5	DPDT miniature
R24, R25	82Ω 1/2W wirewound	S2	SPST miniature
R26	330k	S4	SPDT miniature
R27	500k 20T trimmer, top adjust	S6	On-off part of vol. control
R29	1.5M	Other	Screws, nuts, lockwashers, knobs, standoffs, penlight battery holder (for six batteries), enclosure, etc.
Notes: All resistors 1/4W unless otherwise specified. All capacitors 16 V unless otherwise specified. Output transformer and speakers available at Radio Shack.			

Table 1. Parts list.

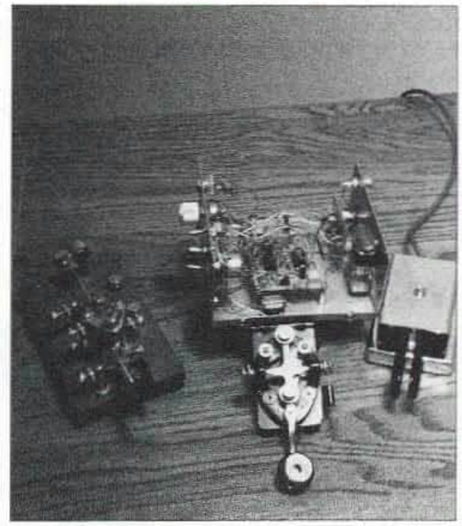

Photo A. *A right fancy CPO.*

Bibliography

1. *New IC FET Principles and Projects,* by Sessions and Tuite; TAB Books 1972.

2. *TTL Cookbook,* by Don Lancaster; SAMS publication.

3. *MOS Digital IC's,* by George Flynn; SAMS publication.

4. *Practical Design with Transistors,* by Mannie Horowitcz; SAMS publication.

5. *CMOS-M Designer's Primer and Handbook,* by Jack Streeter and Robert M. Glorioso; E&L Instruments Inc. publication.