

# All Things Digital

Amateur Radio for the 21<sup>st</sup> Century  
O35

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## The “Cricket”



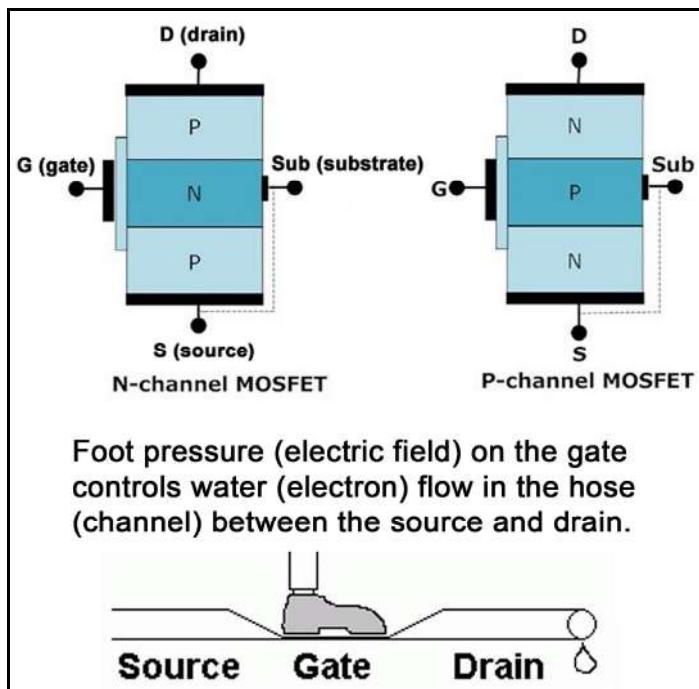
### Introduction

It took a few decades, but the venerable Pixie 2 has finally been redesigned to fix its inherent problems and improve upon its lacklustre performance; just two component changes have made all the difference along with a new name. The Cricket (above) is designed by Dave Cripe, NM0S, and is kitted/sold by the Four States (Arkansas, Oklahoma, Missouri and Kansas) QRP (4QRP) group.

Like the original Pixie 2, it's a continuous wave (CW) direct conversion (DC) very low power (QRPp) transceiver. The Cricket made its debut at the regional "OzarkCon 2017" QRP radio festival, which is held every year by the 4QRP group. For the past two years, Dave's 80 metre (m) and now his new 30 m band Cricket (OzarkCon 2018) were selected for their group kit building sessions. It's an innovatively designed, self-contained, easy to build Amateur Radio kit, and also well-suited for group/class training/teaching radio and electronics in science, technology, engineering and math (STEM) programs. After receiving Cricket 80 user feedback, Dave made some subtle changes to it resulting in the "80a" version (July 2017). His new Cricket 30 copies that design except for the required radio frequency (RF) oscillator and lowpass filter (LPF) frequency specific component changes.

Paraphrasing the Four States web page promo... "The Cricket is a low cost entry level, fun, minimalist, crystal controlled, one watt transceiver. Built on a high quality printed circuit board (PCB), using through-the-hole standard value components, it includes automatic 600 Hz transmit frequency shift, full break-in keying (QSK) with signal shaping, and a sidetone oscillator. This innovative design uses (mainly) the metal-oxide semiconductor field effect transistor (MOSFET), along with a modern bridge-tied-load (BTL) audio amplifier. Dave's famous etched on the PCB spiral inductors mean that there are NO TOROIDS to wind! A simple PCB straight key is included for manual transmitting, but an add-on keyer adapter is provided for those who prefer automatic sending."

And if you think that simplistic/minimalistic DC transceivers are something to turn up your nose up, in the December 2017 issue of *QST* you'll find a very detailed semi-technical review written by *QST* editor Steve Ford, WB8IMY. He performed a variety of tests, and one result really caught my eye—the Cricket, when powered by its onboard 9 volt alkaline battery, only uses 6 millamps (ma) in receive mode—simply amazing! It consumes about 160 ma in transmit mode producing 3/4 to 1 watt (W) power out to the antenna.



**Figure 2:** MOSFET simplified structure and operation. Credit: Electronicshub.org.

### A Transistor by any other Name...

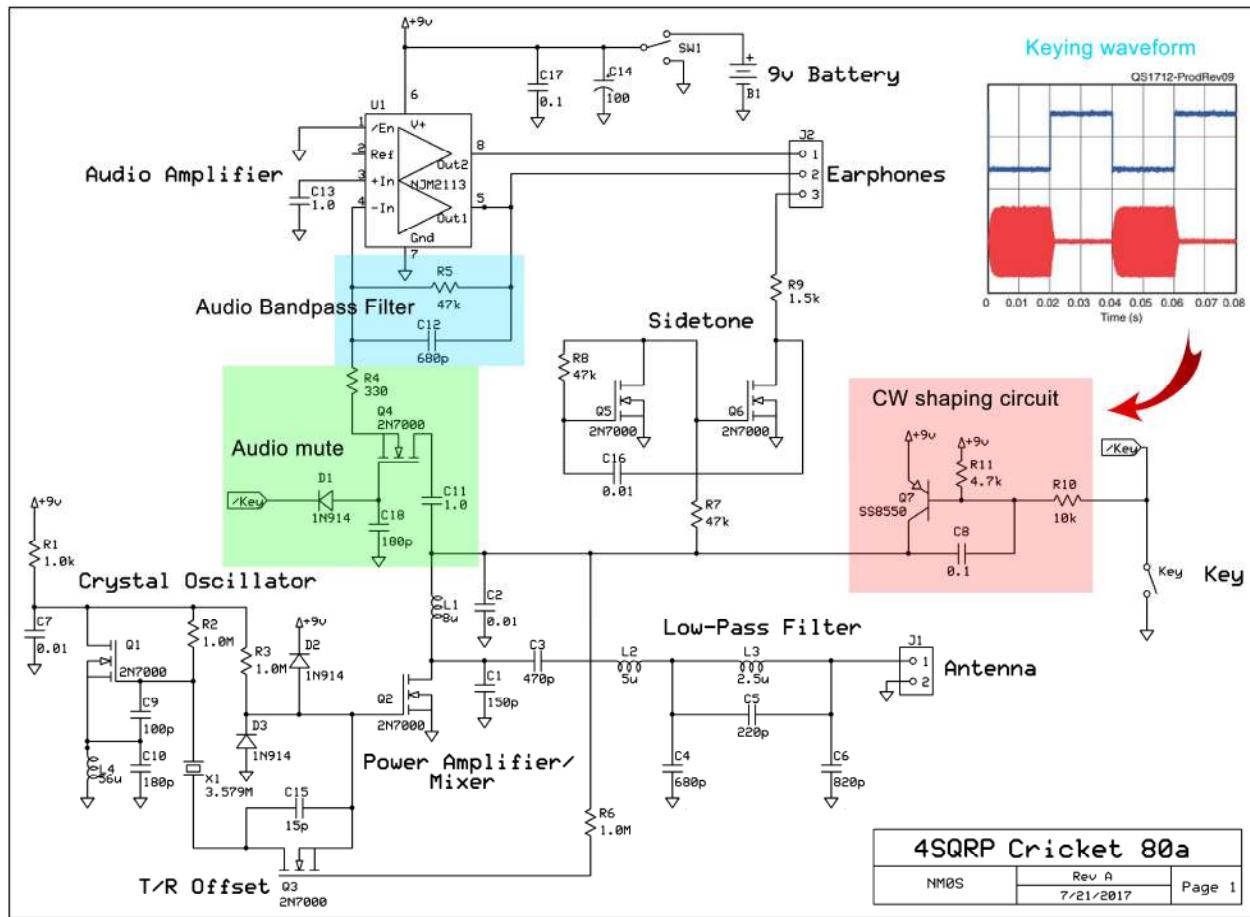
Except for one bipolar junction transistor (BJT) and integrated circuit (IC) audio amplifier, the Cricket uses the 2N7000, N-channel, enhancement mode MOSFET (see Figure 2), which is used as a voltage amplifier and on/off electronic switch. The MOSFET is a “unipolar” device because it only uses one charge carrier to do its job, either the electron or electron hole (N-channel uses electrons and P-channel uses electron holes). Therefore it can handle much higher voltages and currents, has faster switching speeds, and is more energy efficient than the BJT. A MOSFET generates a capacitive voltage field effect when a small voltage is applied to its gate, which is insulated from the silicon substrate, and this controls a large voltage by expanding/contracting as the gate voltage varies, decreasing and increasing electron (or hole) flow in the source to drain channel; basically, it’s a voltage controlled variable resistor. Because of the insulated gate, it has a very high input impedance (many megohms)—a good thing when dealing with weak RF signals—but this also makes it very static sensitive so it’s easily destroyed if improperly handled (the BJT is much harder).

As aside, all attempts in the mid-1940's at AT&T Bell Laboratories (now Nokia Bell Labs) by the team of Bardeen, Brattain and Shockley, to create a voltage field effect solid-state device failed miserably (the triode is the vacuum tube FET equivalent and this is what they were trying to emulate). In trying to figure out what went wrong, they discovered that they had actually created a current controlled solid-state device! This was called a point-contact transfer resistor or "transistor". In the late 1950's, Bell Lab's Mohamed Atalla and Dawon Kahng solved the solid-state substrate problems that had plagued Shockley's team and created the first practical FET followed by the MOSFET.

### **Cricket versus Pixie**

With reference to the Cricket's schematic diagram (see Figure 3, next page), starting from the RF filter and working backward:

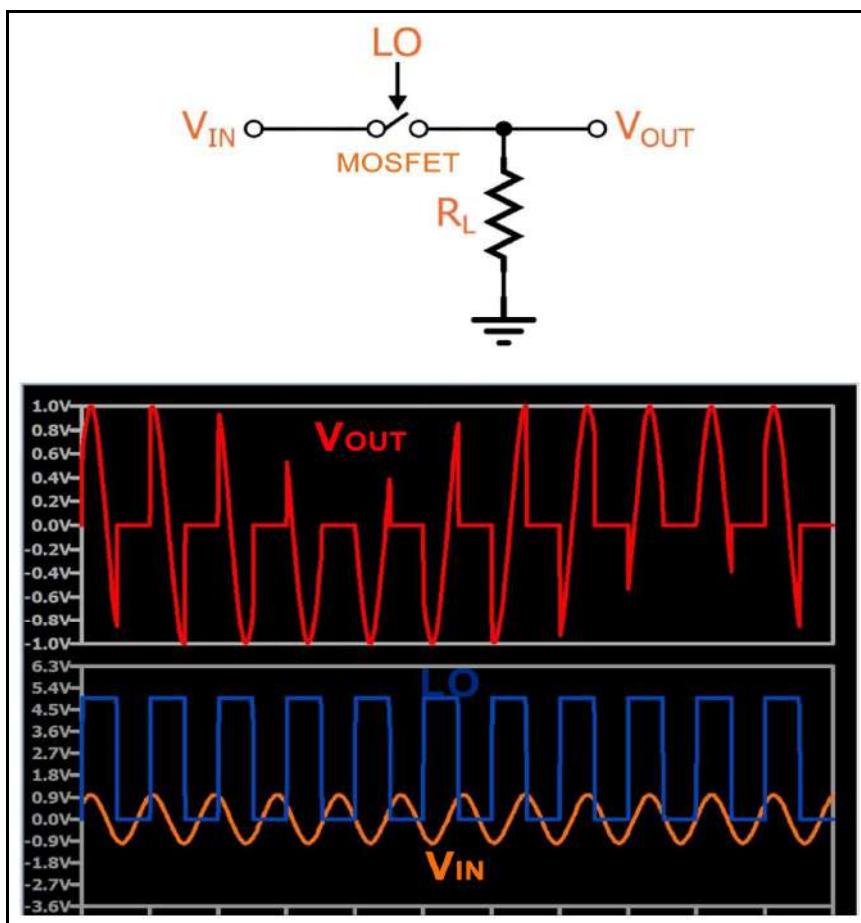
1. It has an effective, efficient, and innovatively designed Cauer or elliptical lowpass filter (LPF) etched on the circuit board that provides the required harmonic attenuation for this class of transmitter, which is at least 43 dBc (decibels-below-the-carrier). The Pixie 2's PI filter doesn't even come close to this and *always* requires an appropriate add-on LPF.
2. The far more efficient class-E power amplifier (PA) is used. At around 90% efficiency (more power out, less wasted energy and heat), it's far superior to the Pixie 2's BJT class-C PA (about 70% efficiency).
3. The receiver minimum discernable signal (MDS) noise floor, or sensitivity is -110 decibel-milliwatts (dBm) or 0.71 microvolts ( $\mu$ V), which is 9 dB more than the Pixie 2's "okay, but..." -101 dBm (2.0  $\mu$ V). But the Cricket, as do all simple DC receivers, still lacks signal selectivity because of its extremely wide passband, so you'll need to add an ancillary audio processing device (analog or digital) to help pick out specific signals from the crowd. See my "The Pixie 2: Part 2".



**Figure 3:** Cricket 80a Schematic. Extra highlighting and annotations added to point out some of its interesting features. Credit: Four States QRP Group. Keying/shaping circuit waveforms graph (insert) used with permission, December 2017 *QST*; copyright ARRL.

4. In receive mode, the Cricket uses its MOSFET PA as a switching mixer (see Figure 4), which makes it less susceptible to interference from commercial AM radio broadcasters (BCI) as compared to the Pixie 2's beat frequency oscillator (BFO) mixer (it's LM386 audio power amplifier is also very susceptible to BCI). A switching mixer has better strong signal handling capability (dynamic range) and adds less noise to the signal. It works a bit differently from the diode/BJT detector, but you still get the same product frequencies: the sum (RF) and the audio frequency (AF) difference.

For example, an LO of 3730 kilohertz (kHz) mixing with an RF signal of 3731 kHz produces an AF difference of 1 kHz. But there's a caveat here because another RF signal at 3729 kHz also produces the same AF difference! All DC receivers have this kind of ambiguity unless one sideband is suppressed before both get to the audio amplifier stage (your brain, in this case).



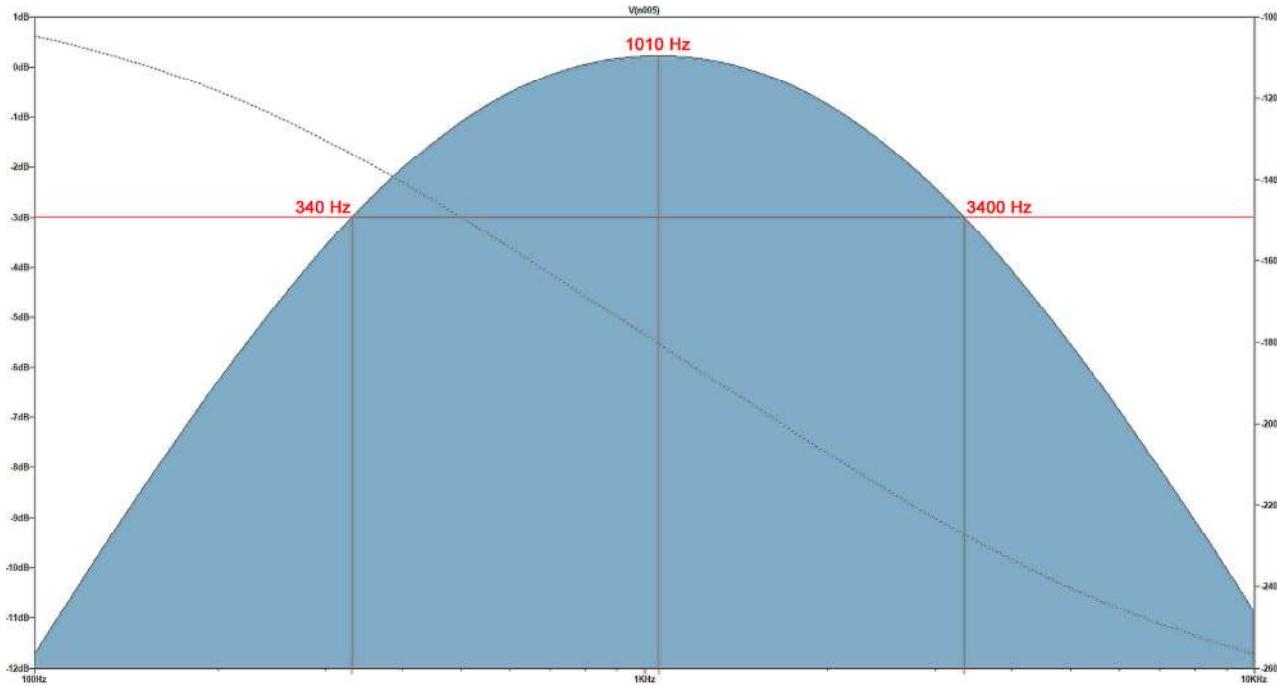
**Figure 4:** Switching Mixer (Simplified). The MOSFET mixer (top image) switches on/off at the LO (carrier) frequency and mixes with an incoming RF signal to produce an RF sum and an AF difference. The bottom image depicts an RF sine wave mixing with an LO square wave (a sine wave plus its odd order harmonics), and the resulting difference. The RF BFP shapes and smoothes the  $V_{OUT}$  signal making it more sinusoidal. Credit: AllAboutCircuits.com.

5. There's a built-in Morse code sidetone oscillator with a nifty, made from PCB straight key, but an electronic keying adapter is included. A simple BJT electronic switch combined with a resistor-capacitor (RC) filter shapes the leading/trailing (attack/decay) edges of the keyed carrier.

Shaping the on/off (Morse code) carrier minimizes “hard” transmitter keying (key clicks) and the odd-order harmonics generated; recommend signal shaping time is just under five milliseconds (ms). But this single-pole filter (one reactive component) isn’t quite symmetrical, so it has a slightly harder trailing edge, but this helps weak CW signals stand out a bit better from noise to a listener’s ears.

6. There’s no variable crystal frequency oscillator (VXO) for tuning around the band, so you are “rock bound” to just one (carrier) frequency at a time, but KC9ON.com offers a variety of single and crystal band packs. But if you operate CW propagation or telemetry beacons, or monitor W1AW data mode bulletins, being limited to one frequency isn’t an issue. And most of the time, you can just sit in place on one frequency and make them come to you by calling “CQ”.
7. A built-in automatic transmit/receive (T/R) offset switch shifts the crystal frequency about 600 Hz provides for lightning fast and smooth switching (QSK), which is also a characteristic of the Pixie 2 albeit it’s rather hard keying because it has no shaping filter circuit.
8. There’s an audio muting MOSFET electronic switch during key down times that avoids the Pixie 2’s QSK problem with its audio coupling capacitor’s charge/discharge cycles being amplified by the LM386, which creates loud and hard on the ears clicking in your headset.
9. An NJM2113 BTL (bridge-tied-load) audio amplifier with audio bandpass filter (BPF) replaces the easy to overload, noisy, and often unstable single-ended (common input/output ground circuit) LM386 audio power amplifier. The BTL amplifier splits the audio signal and feeds one internal amplifier with an in-phase audio signal along with a second amplifier feed with an anti-phase audio signal (differential or opposite polarity); this reduces audio noise, doubles the output voltage across the load, and also isolates the output from the ground circuit preventing ground loops that create feedback, instability, and added noise, etc., which are problems all too common with the “ancient” LM386.

Figure 5 depicts the audio response curve characteristics of Dave's simple audio RC BPF. He calls it a "single-pole cascaded low and highpass audio filter". *Note: When plugging in a headset, speaker, etc. into the Cricket's audio out stereo or TRS (tip, ring and shield) jack, you must always use a matching TRS plug (else poof!).*



**Figure 5:** BTL Audio BPF Filter Curve. The audio bandpass filter (BPF) is centred near 1000 hertz (Hz), with its half-power (-3 dB) points at 340 and 3400 Hz (bandwidth 3060 Hz). The signal to noise ratio (SN or SNR) is increased, while signal interference, low frequency "rumble" along with high frequency hiss or "white" noise is reduced. Credit: David Cripe, NMOS.

## Modifications and Additions

I asked Dave if the Cricket could be operated from a 12 volt battery, and he said "Yes, but you will have to watch the PA for signs of overheating." So a heat sink "hat" would be a good thing to add. Dave confirmed that you can swap the 2N7000 MOSFET PA for a BS170 because it can handle twice the current, however the BS170 source/drain leads are reversed so you *must* remember to install it "backwards" when replacing it for a 2N7000 (else poof!).

I usually add Swiss pin female headers to specific PCB areas where I want to swap in/out components for experimentation, to make it easier to physically separate specific stages when required (the Cricket's PA and crystal areas are two good spots for this). There's also plenty of free space on the PCB to attach (float) smaller PCBs and add additional circuits like a PICAXE controlled CW keyer or propagation beacon (see chapters 8 and 10, "Ham Radio for Arduino and PICAXE"). Or adding an AD9850 based direct digital synthesis (DDS) variable frequency oscillator (VFO) for full band coverage (see chapter 16, "Arduino Projects for Amateur Radio"). But if you really want something smaller, more versatile VFO with a graphics display, ozQRP.com sells a complete and easy to build Si5351 DDS VFO kit with an small but tack sharp organic light emitting display (OLED). These types of displays use very little current, require no backlighting, and are very readable even in bright sunlight and total darkness.

If you prefer semi instead of full break-in (as I do), Dave says you can shunt diode D1 with a one megohm resistor and add a parallel 0.1  $\mu$ F capacitor with C18 (both added on the underside of PCB). This creates a delay of around 100 ms before MOSFET Q4 switches back from transmit (audio mute) to receive (audio on).

## **My Final**

In conclusion and my humble opinion, the Cricket is a far superior and all-around better performer than any Pixie 2 (or clone thereof) DC transceiver. It raises the bar higher, and it should be the de facto 21<sup>st</sup> century template for all Amateurs to use from now on when designing minimalistic DC transceivers. I would like to thank Dave Cripe, NM0S, for his invaluable technical assistance and support in preparing this article.—73