

All Things Digital

Amateur Radio for the 21st Century
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The Pixie 2: Part 1

Pixie \ 'pik-sē \ (noun): In folklore, a tiny supernatural being with magical powers, or a fairy-like or elfin creature, especially one that is mischievous but not harmful; or a tiny Amateur Radio very low power (QRPP) transceiver.

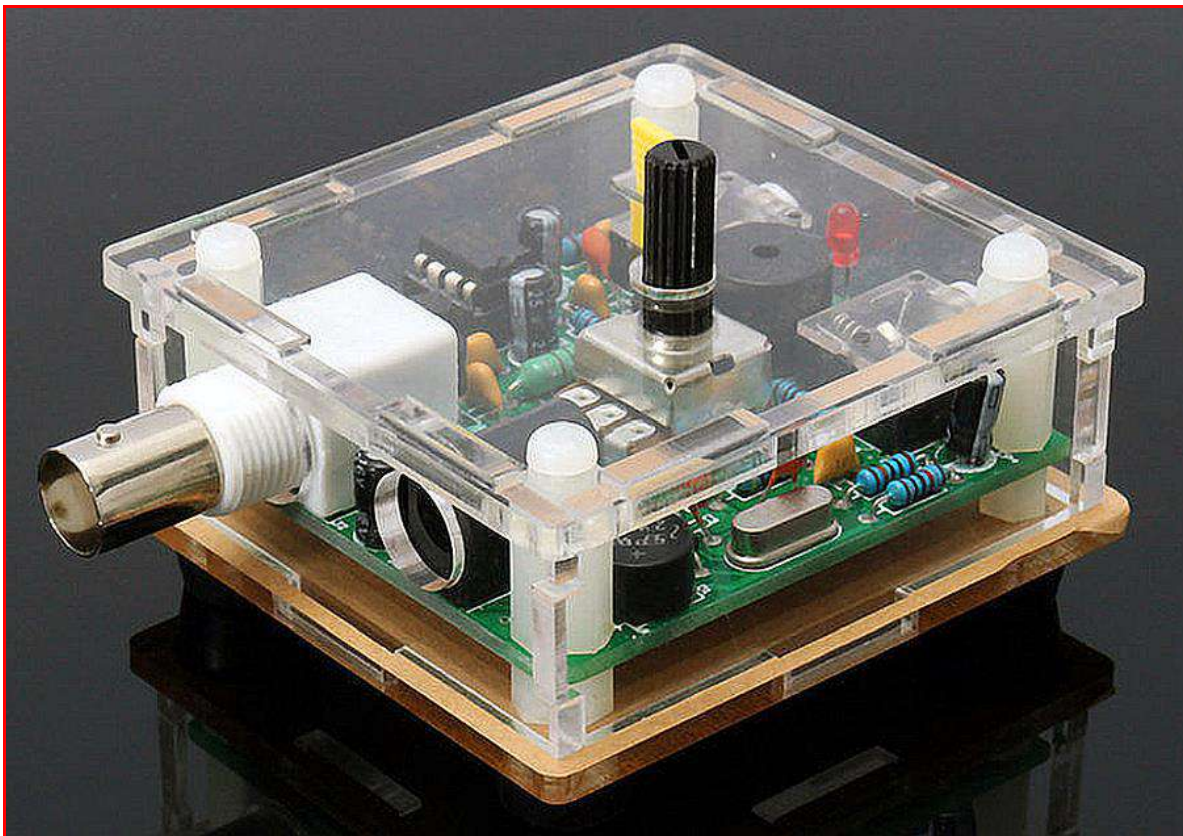


Figure 1: A 21st century Chinese Pixie 2 clone housed in an acrylic skeleton case with added circuit features. Credit: eBay.

Introduction

Okay, that last part of the above definition isn't quite in the Oxford dictionary, but there are very few electronic devices such as the "Pixie 2" that have become legendary in their own time and an integral part of Amateur Radio history. It's a late 20th century, truly mediocre, less than one watt (QRPp) continuous wave (CW) direct conversion (DC) transceiver that's now regaining popularity in the late 2010's thanks to all those insanely inexpensive Chinese variants sold on eBay (see Figure 1, previous page). In Chinese mythology the *Pixiu* is a fierce winged dragon-lion creature with deer's antlers, something the "cuddly and cute" Pixie 2 definitely isn't, but the Chinese QRP design community has come up with cuddly and cute enough [translated to English] names for it like "worker bees", "frog sounds" and "leather shoes", etc. Yet despite its many faults, foibles and truly lacklustre performance, it still has some kind of magical charm many Amateurs just can't resist (I have a half-dozen different varieties in my shack). This is the story of the Pixie 2; it was born in Britain, grew-up in Russia, travelled to the United States, and now has Chinese "cousins" being exported around the world. For the past three decades it has been analyzed, modified, hybridized, and has spun off enough variations to make your head spin. But how on Earth can something so simple be so sublime? To borrow a quote from Churchill: "It is a riddle, wrapped in a mystery, inside an enigma."

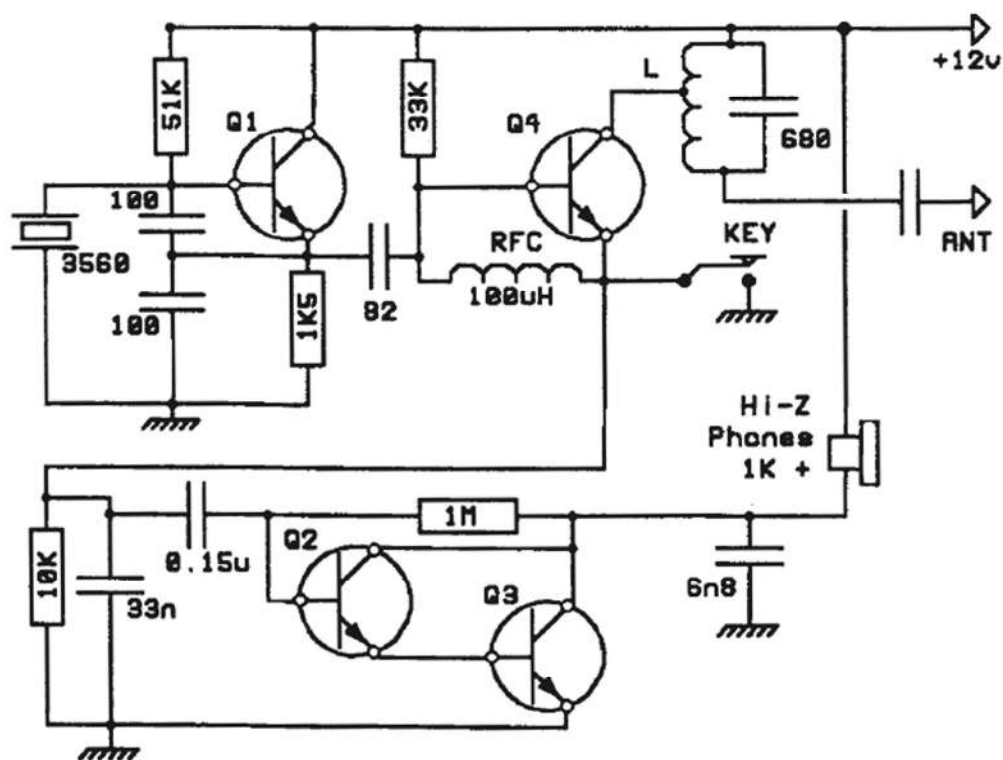
In the Beginning

Not surprisingly, "success has many fathers", but I've traced the Pixie 2's genealogy and provenance back to specific Amateurs by following the actual printed paper trail (thankfully digitized and online). In 1982, George Burt, GM3OXX created the "Foxy", which was a five transistor QRP DC transceiver, and he wrote about it in the 1983 summer issue of *SPRAT* (the journal of the famous G-QRP club). It was the first known (meaning published) Amateur Radio DC transceiver design using the same bipolar junction transistor (BJT) for both the receiver mixer and transmitter power amplifier (PA) stages. The Foxy is considered the grandfather of all things Pixie, and a 21st century enhanced version kit of it is sold as the "Foxy-3" by Kanga UK (see Figure 2, next page). *Note: A bipolar junction device uses both the electron and electron hole (a lack of electron) charge carriers to do its job.*



Figure 2: Kanga Products UK sells the Foxx-3 kit. It's a redesign of the original done by Derek Alexander, G4GVM (1999 spring *SPRAT* refers). It sits nicely inside the classic Altoids mint can. Credit: Kanga UK.

In the late 1980's, Oleg Borodin, RV3GM designed his "Micro-80" QRP DC transceiver by combining two earlier separate Russian DC receiver and transmitter circuits, and he did it using only four transistors (Amateurs are frugal, if anything!). He logged his first two-way contact (QSO) on 2 March 1989 with a Leningrad Amateur, and this design was published in the 1992 autumn issue of *SPRAT* (see Figure 3 schematic, next page). The Micro-80 is undisputedly the de facto father of the "Pixie 1", which would later become the Pixie 2.



But both the original Foxx and Micro-80 used high-impedance (“hi-Z”) headphones or “cans” (impedance greater than 1000 ohms), and they were only designed for use on the 80 metre (m) band because atmospheric noise here is the limiting factor instead of receiver sensitivity. The published sensitivity was “about” 2 microvolts (μV) with a minimum discernable signal (MDS) or noise floor of minus 101 decibel-milliwatts (dBm), which is around an equivalent signal strength unit (S-unit) meter reading of S4-1/2. The MDS is the point where a signal is 3 decibels (dB) above the noise; for CW this is measured using a 500 hertz (Hz) bandwidth. *Note: Noise is defined as anything that interferes with the desired information signal. Using the Pixie 2’s DC receiver on the 30 m band (and up) becomes more of an issue because more signals will be below its MDS.*

West Coast Cloning

The actual Pixie 2, which we all have come to know and love (and hate at the same time), originated from a design by David Joseph, WA6BOY called the “Tiny Rig” (a Micro-80 variant). He was the one who added the now ubiquitous LM386 audio power amplifier integrated circuit (IC) to provide an enormous amount of baseband (audio) amplification, and it also allowed the use of low impedance (“low-Z”) or 8 to 32 ohm headphones and/or external speakers. He first told the QRP world in the 1993 issue #1 of *QRPP* (the also famous Northern California [NorCal] QRP Club newsletter) under the title “The Pixie 2, 80 Meter Transceiver” (see Figure 4). Interestingly, he also added an optional series tuned Colpitts (formerly Clapp, 1948) circuit for manually pulling (bending, warping or “rubbering”) the crystal’s frequency using a variable capacitor, and also added a Morse code sidetone circuit to block out the headphone key clicks caused by the rapid audio coupling capacitor’s charge/discharge cycles amplified by the LM386, which were usually omitted in a minimalistic Pixie 2

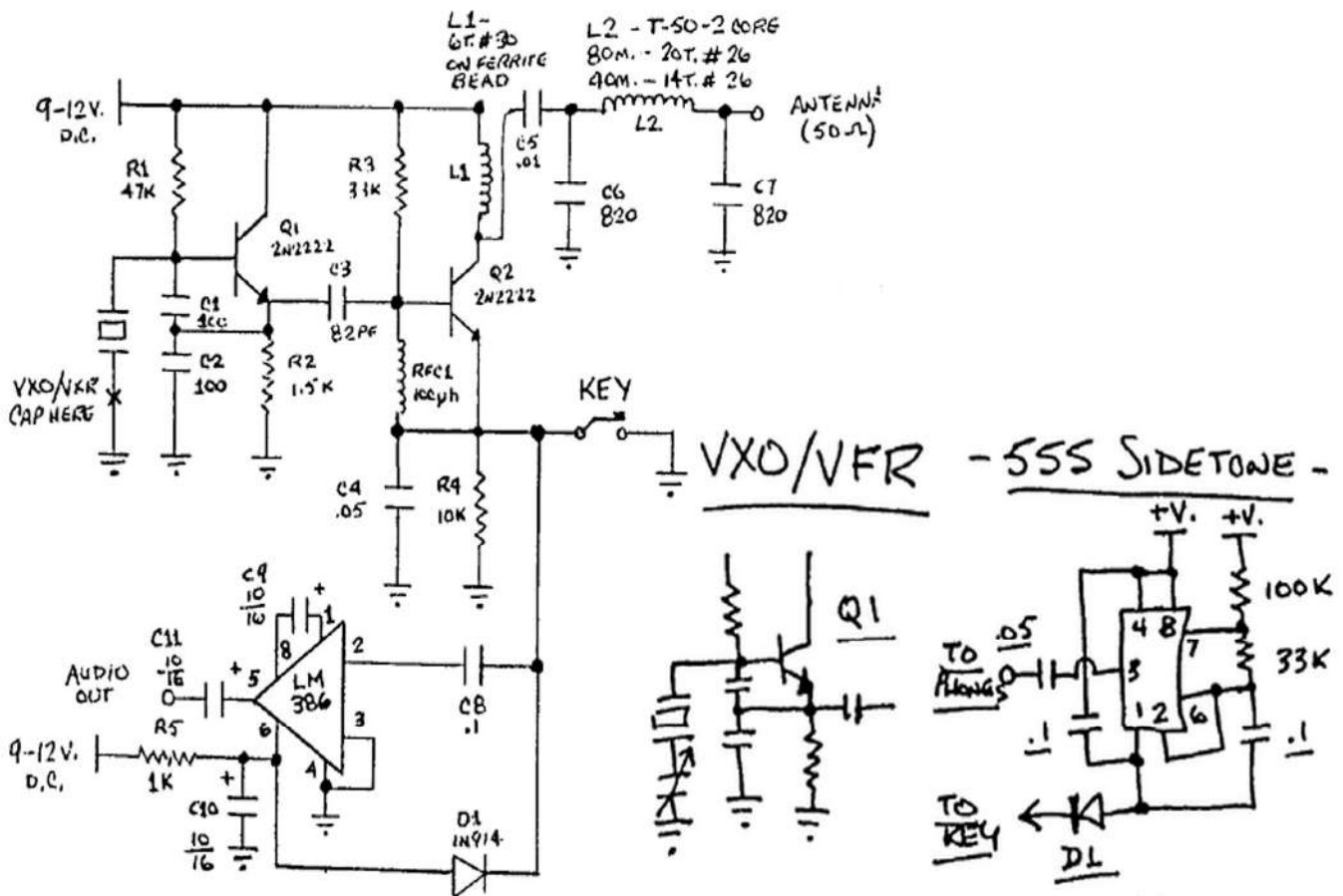


Figure 4: The WA6BOY original (1993) Pixie 2 schematic with ancillary circuits. Credit: *QRPP*.

Note: George, Oleg and David all demonstrated very strong reasons for publishing their designs in widely read QRP/QRPp periodicals along with keeping accurate logs and/or notes because he who publishes first gets all the credit and fame!

Pixie Mixing “Magic”

No, it’s not because of any enchanted magic pixie dust—or *IS* it. Nope. It’s actually the superlative or sublime simplicity of the design versus its performance when compared to other radio circuits (regenerative, superregenerative or superheterodyne). A direct conversion (homodyne, synchrodyne or zero-IF [intermediate frequency]) receiver uses the simple principal of heterodyning or non-linear mixing (beating) of radio waves, which was discovered in 1901 by Canadian wireless pioneer Reginald Fessenden. In a DC receiver, an incoming radio frequency (RF) signal is mixed in a non-linear fashion with a second RF signal generated by a local oscillator (LO). This is [algebraic] mixing and it creates a pair of new signals: the difference and the sum of the first two (see Figure 5).

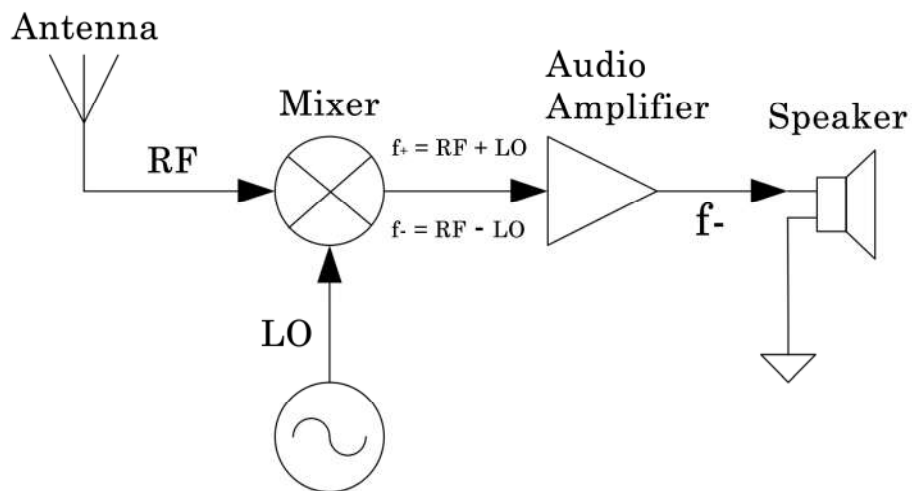


Figure 5: Direct conversion principle.

Because these new frequencies are called products, mixers are often referred to as product detectors, while the DC receiver LO is often called a beat frequency oscillator (BFO). The difference is an audio frequency (AF) or baseband signal, and the sum is a third RF signal. In the case of a DC receiver, all RF signals are discarded upfront and only the audio signal is processed.

Various types of non-linear, two-terminal (diode) devices (mercury, galena, germanium and silicon), have been used since the early 20th century for the detection of radio waves. These waves cause electron flow (current) in things we stick up in the air in their way (antennas), and diodes control the flow of electrons and steer them in one specific direction, and they also add less electronic noise or distortion to incoming signals when used for radio wave detecting/mixing because they are passive (unpowered) devices. But because of this fact, they also have insertion or conversion loss and can't amplify, which means that which means weaker signals won't be detected. Their opposites are active (powered) devices (such as transistors), and these can amplify weaker signals, but they can also add more noise and distortion to weaker signals. *Note: Non-linear means that the mathematical relationships between voltages and currents in a circuit (passive or active devices) aren't straight line or linear (proportional), and therefore don't obey Ohm's law where $E = IR$ (we ignore any signal phase shifts); another term for this is non-ohmic. Semi-conductors or solid-state devices (transistors, diodes, et al) are non-linear/non-ohmic, while capacitors and inductors are linear/ohmic. However resistors can be regular ohmic carbon or metal film types, or very non-ohmic varistors, thermistors or light dependent variants.*

Pixie Anatomy

There are five stages to the Pixie 2 (see Figure 6, next page): local oscillator, combined mixer/power amplifier, RF lowpass filter, audio amplifier, and keying control.

1. LO

This is one circuit all QRP enthusiasts easily recognize; it's a simplified version and variation of the classic Colpitts oscillator (Colpitts, 1918). It's probably the most versatile, flexible, widely used and popular RF oscillator design of all time. You know it's a Colpitts because of the centre-tapped two series capacitors in parallel with a crystal (sometimes an inductor), which creates a resonant frequency "tank" circuit (as in a water tank that fills or empties with water, or in this case electrons). When voltage is applied, the tank oscillates by exchanging RF energy back and forth between the capacitors and crystal at a fixed frequency. A transistor amplifies this energy and passes it on to the next stage, but it also sends some energy back to the tank circuit using positive (in phase) feedback or regeneration (Armstrong and Meissner 1912/13).

Without this, the tank circuit would quickly stop oscillating (run dry). Because you're also fixed to just the one frequency, as determined by the crystal (made from a piece of quartz rock), you are said to be "rock-bound".

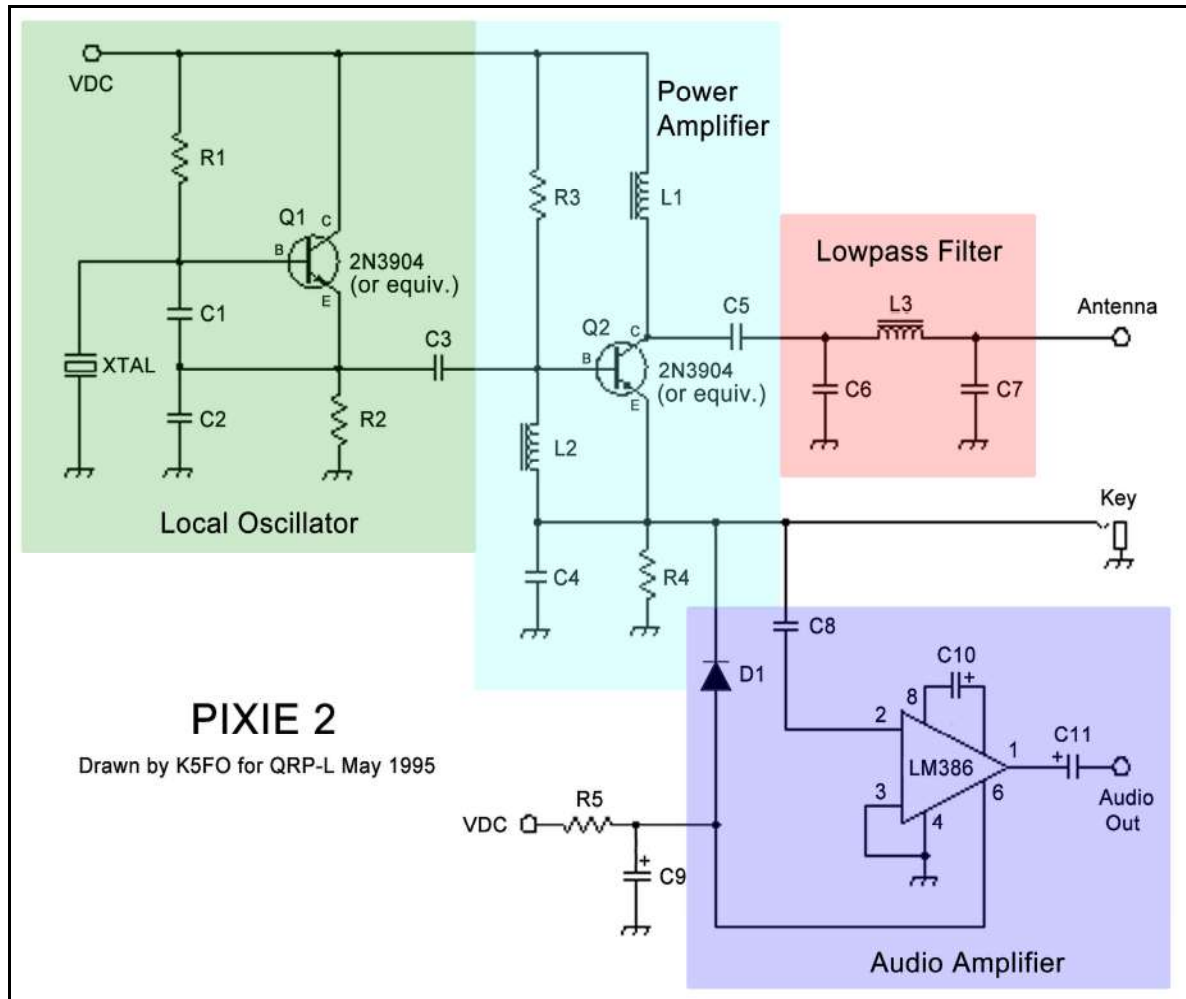


Figure 6: PIXIE 2 circuit structure. Credit: *QRPp*.

2. Mixer/PA

Today, it may seem so simple and obvious to us, but back in the early 1980's the typical QRP mixer and PA circuits were used separately. But because a transistor can be modeled as two back-to-back or front-to-front diodes connected together with a [current] control line, George, GM3OXX realized it could work like a diode [single ended] mixer, and also amplify signals (RF and AF) to make up for insertion loss.

A transistor used like this is called a single ended mixer because it's not balanced (prevents the two mixed RF signals from leaving the mixer), and some very weak LO energy continuously leaks through to the antenna and out to the local reception area, which is very useful for tuning/monitoring by using a second, nearby receiver.

3. RF Lowpass Filter

This type of filter is bidirectional whereby RF signals can enter/exit from either side and are affected equally (see Figure 7, next page). It is generically called a "Pi" filter, but more properly, it's a 3-pole, capacitive input or capacitive-inductive-capacitive (CLC) RF low pass filter (LPF). It's called Pi because its shape resembles the Greek letter; 3-pole because it has three reactive components, and low pass because it only allows low frequency signals up to its designed cut off frequency to pass through. Its primary job is to provide for the optimal two-way RF energy transfer between the PA and the antenna and vice versa (usually 50 ohms to 50 ohms). Its secondary function is to sharply attenuate secondary RF signals called "harmonics" from being transmitted from the PA to the antenna.

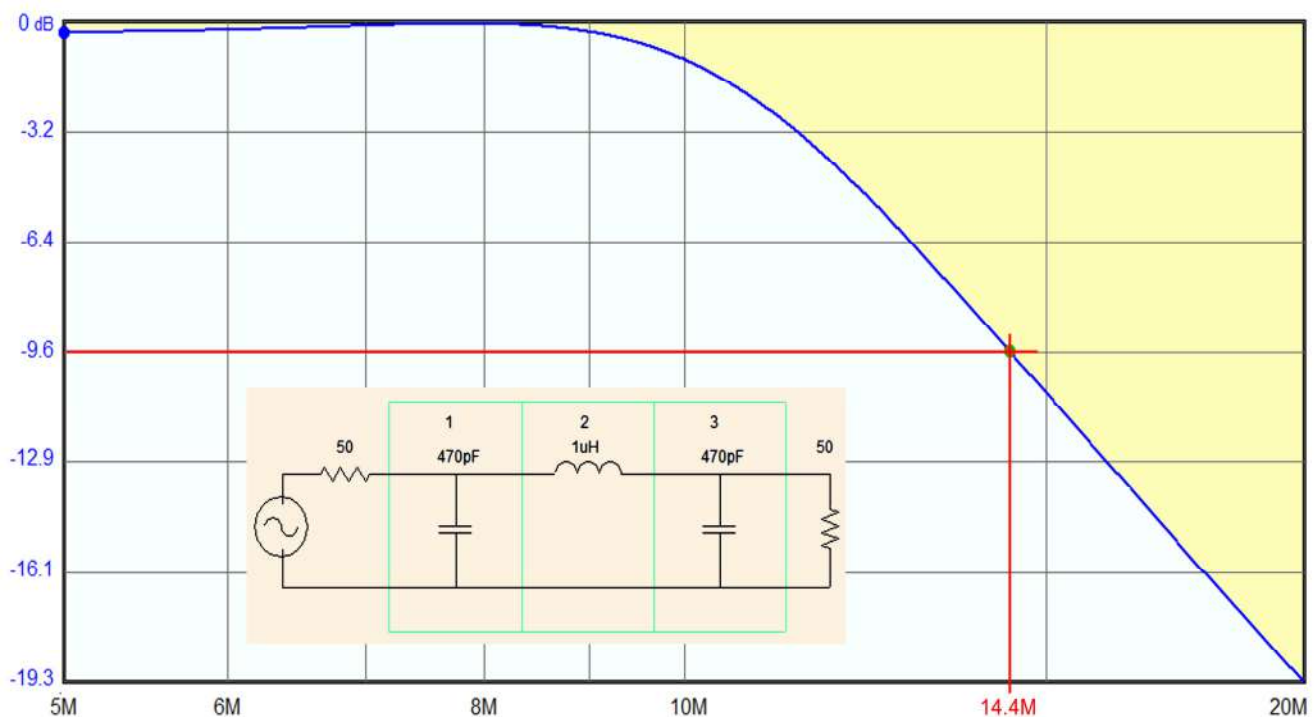


Figure 7: Pixie 2 RF lowpass filter design and frequency response. Credit: ELSIE filter design program.

Harmonics are created when a sine (sinusoidal) wave, composed of just one pure note or fundamental frequency, is distorted and becomes less and less sinusoidal. For example, a square wave is algebraically a sine wave plus every odd harmonic to infinity, so it will definitely create problems when transmitted into the ether. Even a microwatt transmitter can spew horrendous harmonics into the local RF listening area, and your neighbours will definitely NOT appreciate their TVs and/or lights flickering as you merrily key away in Morse code! Most consumer electronics have little (if any) in the way of radio frequency interference (RFI) suppression, and most seem to be really good at receiving Amateur Radio transmissions. *NB: The stock Pixie RF filter DOES NOT meet the minimum harmonic attenuation required by today's international regulations, which is at least 43 dBc (decibels below the carrier), so additional RF filtering must be added BEFORE putting it on the air.*

4. AF Amplifier

An LM386 audio power amplifier is usually configured to run at its maximum gain of 200 or 46 dB. All audio amplification is handled internally so only a few external components are required for it to function. But it's an old, hissy and noisy chip, and it can often get out of control from the very high gain used ("microphonics" and "feedback") and become a howling, squealing amplifier/oscillator! Today there are far better replacements for it, but just like the Pixie 2 it still endures.

5. Key Control

When the hand key circuit is open (key up), RF signals from the antenna pass through the RF filter and enter the combined mixer/PA from one side while the LO signal comes in from the other. Both signals are non-linearly mixed together by the diode-like action of the transistor and amplified. The audio (only) signal enters the LM386 and is really amplified to the limits of the chip's design. When the hand key circuit is closed (key down), the signal path is reversed and the LO signal enters the mixer/PA where it's amplified and exits via the RF filter to the antenna as our on/off keyed (OOK) carrier, while the LM386's power is removed to mute the audio, but as a result you will hear key clicks.

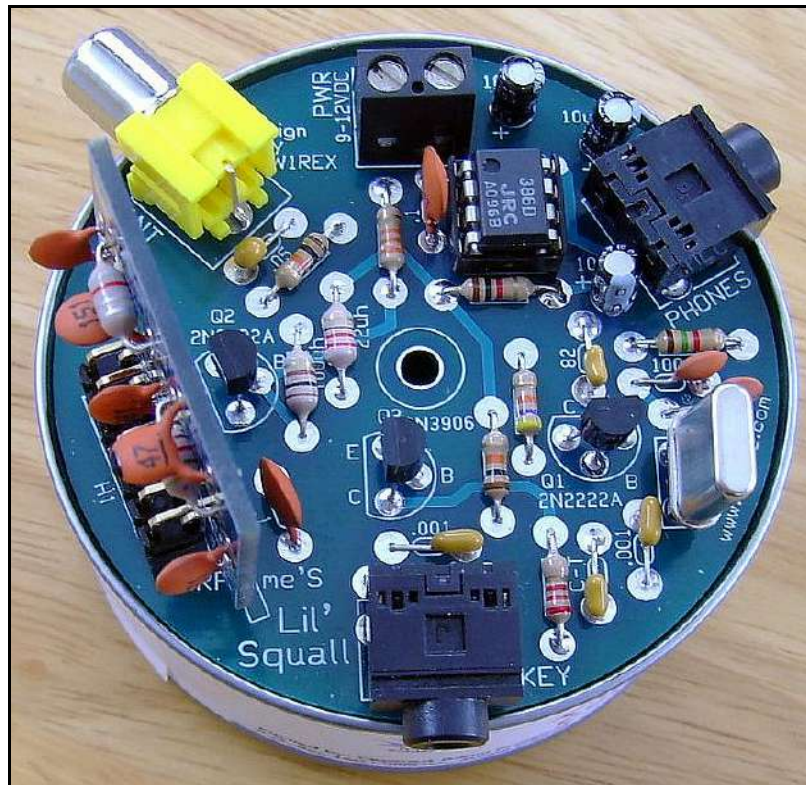


Figure 8: QRPme tuna tin Pixie 2 variant. Credit: QRPme.

Which to Choose?

There's the Foxx-3, which is great for operating a backpack QRPp Morse code portable station (plus it also fixes some problems). Rex Harper, W1REX (QRPme.com) sells very nice variations (right) mounted on tuna tin cans (see Figure 8) instead of inside Altoids tins (if you prefer eating fish over mints). You can also buy a lot of those cheap, basic Chinese Pixie 2 kits for group club/class builds but you will need to rework the RF LPF. Regardless, any version of the Pixie 2 is a great tool to use in the classroom to introduce STEM (science, technology, engineering and mathematics) to students of all ages! For example: how about connecting a Pixie 2 to a Raspberry Pi or Arduino microprocessor to build a telemetry gathering and CW transmission gadget? This may be an excellent way to get a younger generation interested in radio and electronics design, theory, data modes, digital signal processing, mesh networks, etc.

My Final

Part 2 continues with the history and fixes for the basic Pixie 2's design problems and faults, along with adding ancillary circuits to it to enhance its so-so performance.—73