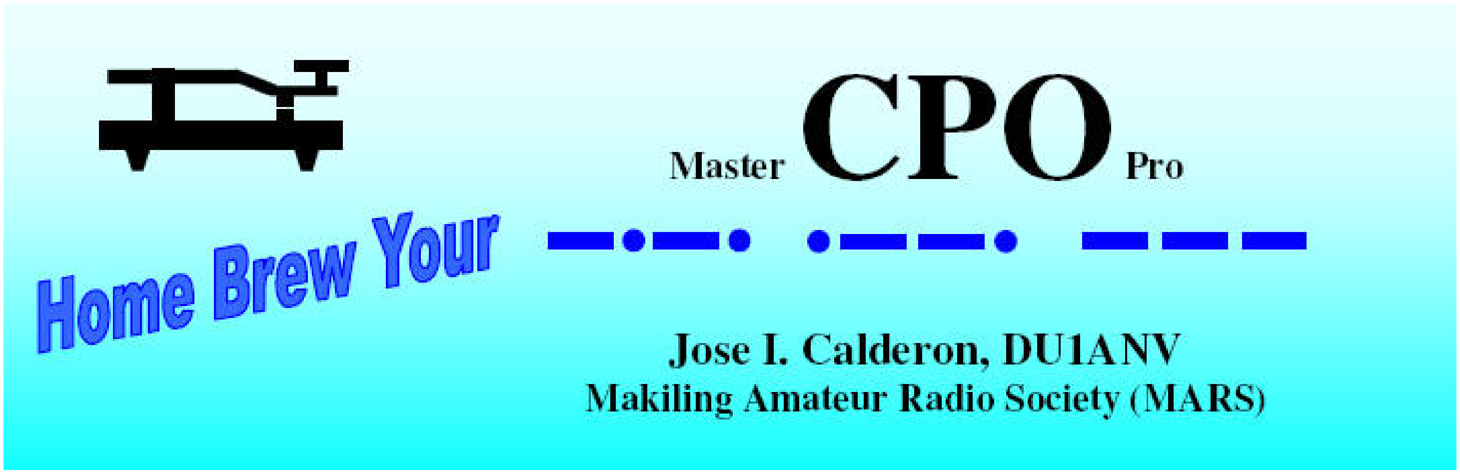

When I started learning the Morse code, there was no tutor to help me in my far away hometown in the North. In order to practice receiving, I have to use my shortwave receiver and listen to the shore-to-shore and shore-to-ship transmissions of RCA, Globe McKay, NPO and NPG signals. I also needed a Code Practice Oscillator (CPO) to practice sending. There were no transistors available here in the Philippines at that time. The semi-conductor technology was still in its embryonic stage and I had to make-do with whatever was available to make the sound of the code characters.

I received my first jolt of electricity when I tried to wire a raw AC to drive a small transformer to bring it down to a manageable potential to operate the door buzzer that I stole from the main door every time I practiced. Of course I had to pretend that the old buzzer was due for repair and maintenance in case my mother would throw inquisitive murmurs why I was always dismantling the old reliable door buzzer. That electrocution pushed me to investigate other possibilities. I was determined to enter the exciting hobby of Ham Radio. I had to master the
code in due time!

As time went by, I tried the use of electron tubes wired in a Wien-bridge configuration. It worked! The tone oscillator output was beautiful, clean and whistled like the beat note heard on CW signals heard on my short-wave receiver. But the circuit required a high voltage source which meant wiring the big power supply. Then the B-plus must connect to the plate terminal of the big tube via the keyer contacts in series. To practice the code, the keyer must "make and break" this high voltage DC to the plate terminal of the tube to oscillate in unison to the strokes of the up and down lever movement as one makes the dots and dashes. It was great even when occasional finger mistakes will receive an electric tingle when it slips to the lever terminals... he he!. By experimentation, I finally discovered that I can eliminate this occasional electrocution by connecting the

high voltage to the plate permanently and then break the cathode connection and insert the key terminals in series. This made my lever contact at ground potential when the key is up. I found later that this technique was at that time being used on transmitters to send CW. Nevertheless, my concern was that the Wien-oscillator and power supply was still bulky and heavy. It weighed about 1 kilogram or more, accommodated bare in a steel chassis measuring 4x8x2 inches. I enjoyed it however because the tone sound was sweet and smooth. And of course,

I enjoyed the pleasure and satisfaction of home brewing. I called that project "Master CPO". Thanks God! I survived the mild electrocutions. I did it the hard way though to practice my CW. At about this time, I was already enjoying my Morse proficiency even before taking the amateur radio examination but felt the need to increase my speed to enjoy receiving the regular weather forecasts by many CW stations in the shortwave bands, including occasional eavesdropping from RCA and Globe McKay transmissions and in later years, the RCPI. Besides, I needed to build up my confidence for when the time came to take the amateur radio examination.

I passed the amateur CW exam with no difficulty. I needed however to modernize my aging master CPO to practice sending perfect Morse characters at higher speeds. I had to design a CPO that would be highly portable, battery operated and not pose any more danger of electrocutions. Of course, the tone must be as pleasing to the ear as in my old CPO or even better to reduce brain and hearing fatigue during long and extended practice sessions.

When the Radio and Electronics Industry begun flooding the local electronic parts dealer shelves with tiny transistorized radios and semi-conductors, I was now ready to try my amateur radio design and home brewing skills.

With the numerous selections of semi-conductor devices, I started figuring out what design I must adopt. The simplest considered was a simple Darlington feedback circuit but I did not like the tone. It was rough, raspy and tiring to the ear. The Integrated circuit came into the picture and so I tried the use of the 555 timer IC. Beside its low audio output, the tone was also not satisfactory. A quick check with my Oscilloscope showed a train of square waves in its output. Only the addition of wave shaping circuits would tame the squares into something closely approaching a sine wave output signal. This entailed additional cost plus, at that time, the 555 IC drained my pocket to get one. I decided to try those designs that produce a sine wave directly without additional wave shaping circuits. This could be a "Wien-bridge" again or I could try the increasingly popular "Twin-T circuit". The Wien is a complicated circuit and so I decided to design my "Master CPO " based on the Twin-T. The circuit had to be simple, cheap, and produce a pure sine-wave signal with no distortion to tire the ear. The tone must be adjustable to be able to tweak and simulate the beat note of a CW signal of Morse code transmissions heard on a receiver. Finally, the same circuit may be used to directly modulate an FM rig to practice CW tone modulated FM and, for other applications that would make it useful in the ham shack.

The prototype was constructed from junk parts retrieved from non-operational AM transistor radios. It used a silicon NPN transistor with a current gain of about 90 to 100. This low gain produced intermittent oscillations but I solved the problem by adding an inductance in the base circuit of the transistor. Apparently, this component provided an inductive kick to force the transistor to break into oscillation at the instant the collector was excited with the supply voltage. It

worked! See the circuit shown in Fig. 1.
In the final circuit, I used a modern NPN transistor (2N3904) with a current gain of about 200. It needed no inductance to oscillate but since the coil was already installed in the homebrewed pc board, I decided to leave it "as is" to provide the feedback path of the T-circuit. I surmised that this inductance may also prevent spurious harmonics that may degrade the desired signal. This version worked perfectly and I called this completed project "Master CPO pro" in 1985.
The principle of the twin-T oscillator: The chosen oscillator circuit (See Fig. 1) is governed by a feedback network of two separate RC constants connected in a T-configuration (often called Twin Tee). When each RC network is excited by the charging voltage at the collector of the transistor, RC network 1 (18KΩ, 18KΩ and the .05µF cap.) and RC network 2 (500Ω, 5KΩ pot and two .02µF cap.) will begin to charge instantaneously and will discharge later (determined by the time constant of each network). This repetition rate will be the frequency (see text below for modifications). The configuration of the circuit is such that each Tee-circuit will oppose the other by virtue of the reversed connections of the RC network in the upper Tee and the lower Tee (low-pass and high-pass filters, respectively). In addition, the output signal of the transistor is fed back but inverted through these circuits to the input of the device, the phase of which is the same as the original base input signal (positive feedback) at the oscillator frequency. Others that are above and below this frequency are out of phase (negative feedback). Hence, the final feed back to the base circuit is regenerative at the oscillator frequency. The characteristic of the Tee circuit (inversion) combined by the high current gain of the transistor used will bring the whole circuit into oscillation.

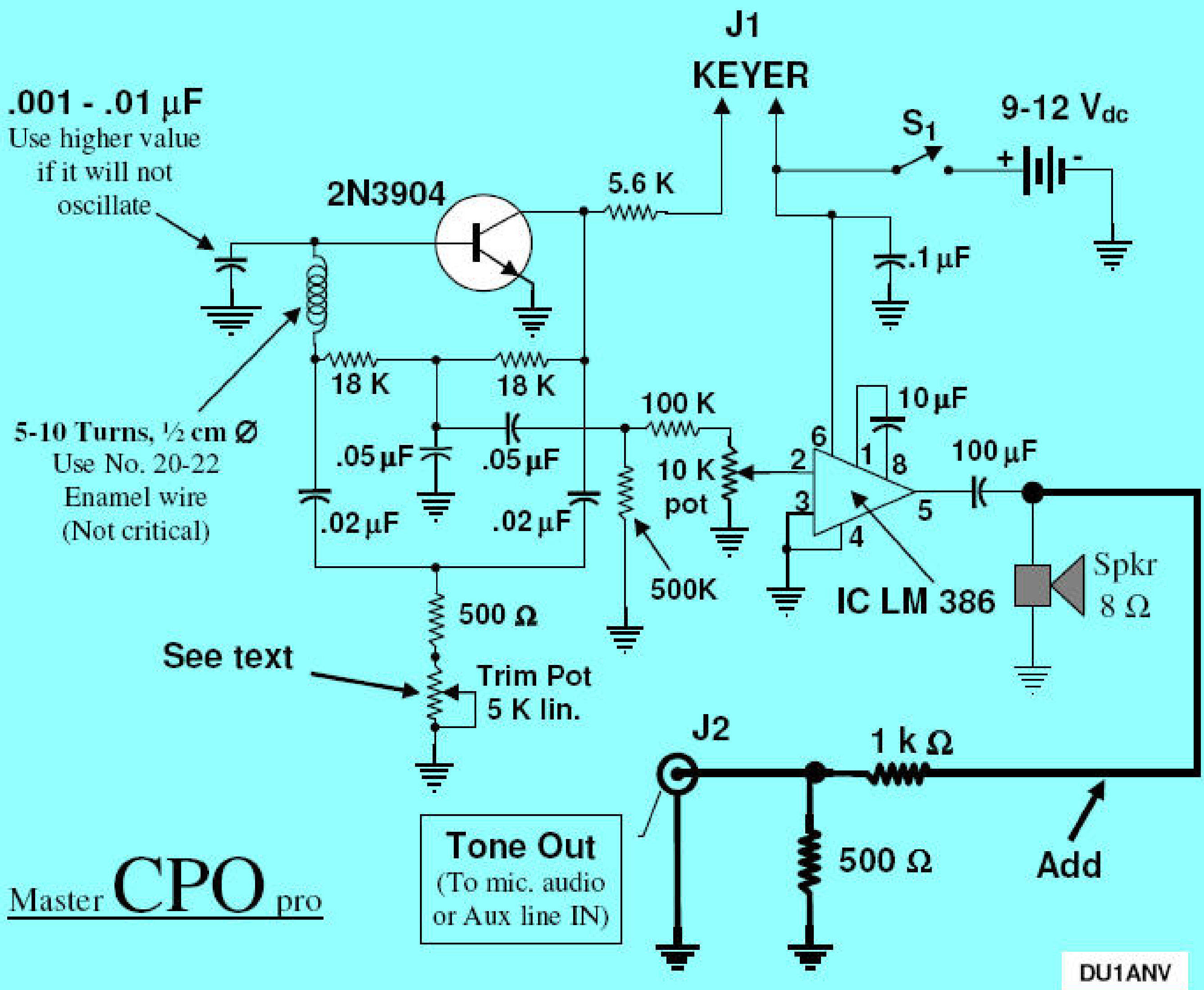

Fig. 1. The master CPO pro circuit for MORSE CODE practice. This audio oscillator will produce a pure sine-wave signal within the range of 500 – 2000 Hz. Part of the output can be tapped from the speaker line (shown in BOLD lines) to modulate an FM Rig or feed an audio amplifier for mass training practice via **J2** (See text description).

The oscillator circuit with the components shown in Fig.1 will oscillate in the audio range. For those amateurs who want to dig deeper into the design parameters of this type of oscillator, the writer recommends that they must read the many available literatures in Radio and Electronics. For the Ham Radio rookie, the operating frequency (Fo) is approximately defined by:

$$F_o = \frac{1,000,000}{2\pi RC}$$

Where:
F = Hertz R = Ohms
C = µF

Of course the amount of feedback (180° phase shift and bandwidth) is determined by the ratios of the two T networks to unbalance the bridge, as required, to oscillate. You can see and analyze these ratios by examining the basic twin-T circuit design values as shown in Fig. 2. This network is also called "a notch filter".

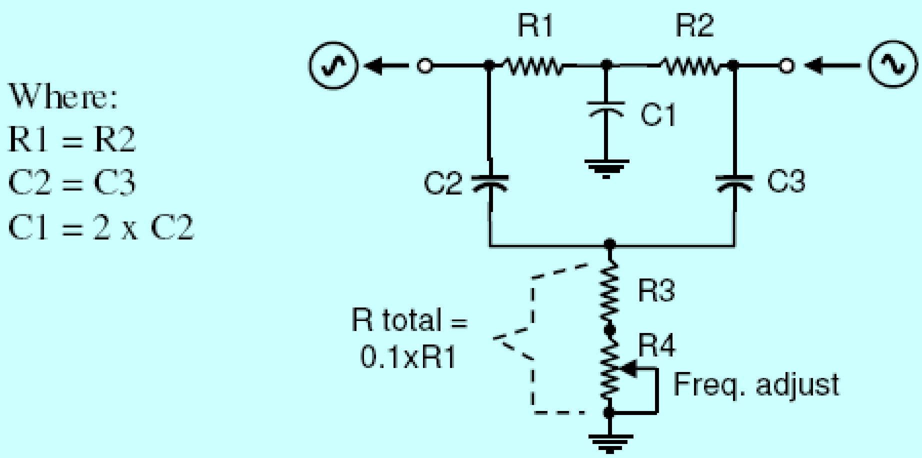

Fig.2. The basic Twin-T circuit design values to oscillate at desired frequency. Note that the feedback signal is inverted.

If a different transistor is used (must be NPN), the circuit may oscillate intermittently due to the differences in semiconductor design parameter characteristics (less current gain). This may be resolved by increasing the value of the bypass capacitor (this is the so called "substitution technique" in home brewing) in the base circuit (see Fig. 1). To change the oscillating frequency is a matter of changing the RC constants of either one of the T-network. The simplest way is to install a variable potentiometer (5KΩ) in series with the lower lead of the resistance leg (500Ω) connected to the lower Tee (the junction of the two .02µF capacitors) instead of the required 1.8KΩ resistor leg (based on calculated), which I did. This will tweak the frequency to the desired tone somewhere between 500 to 2000 Hz. A wider frequency change (swing) can be achieved by making the upper Tee resistors (the two 18KΩ resistors) partly variable but the two must be linear taper type and ganged in one potentiometer shaft to maintain the same ratio of each arm of the Tee. I used this configuration in those completed projects given to other Hams.
Note that in either method, the frequency tone will decrease as the resistance is increased. The output level of the oscillator is low but an IC audio amplifier was added to provide a more than enough amplified output for general use. The output signal of the oscillator was taken from the top of the .05µF upper T-leg through another .05µF coupling capacitor. The output impedance is quite high so

the circuit consisting of an L-network (500KΩ and 100KΩ) was added for impedance matching before the level control (10KΩ potentiometer) in order not to
load the oscillator. I used the standard design for an operational amplifier using the LM-386 integrated circuit. A voltage source of DC to power the whole circuit may range from a 9- volts battery or any well filtered and regulated supply of 9 – 13.8 volts DC will be ideal.

Multiple Uses of the master CPO pro

The final project produced a pure clean sine-wave signal worthy to hear. Indeed it is called the "Master CPO pro". When an IC (LM 386) audio amplifier was added, a good output will suffice to fill the radio room. It can be used to practice a group of 40 trainees gathered in a room. During the regular JOTA activities of MARS, this CPO unfailingly satisfied the interest and curiosity of the young Boy Scouts while doing the Morse code practice sessions.

Another feature was added to the circuit to make it a real professional amateur radio accessory. The additional circuit (see Fig. 1) that is connected to the speaker audio line provides a low impedance source of audio tone. It is a perfect tone source to frequency modulates a 2-meter FM rig for CW tone modulation and deviation testing. Connect a well shielded wire to its tone output jack (J2) then feed the tone directly to the audio line of the mic input plug of the transceiver. To work CW tone modulation, press the PTT or lock the PTT then send Morse code
by using a straight key plugged into J1. By using the same tone output jack, the master CPO pro can be used as an excellent CPO for extremely large training audience. In this case, feed the output into the audio auxiliary input of an audio power amplifier.
Due to its inherent design and coupled with its well known high stability characteristics, other possible applications can only depend upon the user's multifarious needs. I integrated this circuit to my home brewed auto-electronic keyer as a quad-function station accessory. It has provided service as a CPO, side-tone monitor, VHF FM modulator and testing audio distortion problems in amplifier circuits. It is also a perfect test-bench accessory for signal tracing purposes in problematic audio circuits. By increasing the R values, the circuit can oscillate below 200 Hz with high stability. It can be used as a tone encoder for CTCSS tone control applications.
My on the air VHF-CW sessions magnetized Hams to drive all the way to my QTH in Los Baños to see and get the circuit. One Ol'man came knocking at my door one Saturday morning while I was at the Radio room. So I asked who goes there? The answer was ..Telephone Telegraph!!, in a loud voice. At first I did not recognize the voice. A little later, the loud voice came back again. This time he said... this is Ben ... DU1...Telephone Telegraph!! I then remembered a 2-meter CW contact the previous night. It was DU1TT/Ben, from Metro Manila. He hurriedly copied the circuit of my master CPO pro with the usual amateur greetings of course. Said 73 then away he went, back to Manila. Two nights later, I heard his sweet sounding CW in the regular VHF brass pounding sessions, bragging with the familiar Master CPO sine wave tone in the air. Errol came also one day for the circuit for use in his code practice sessions. He is now a CW pro. You can hear his callsign, 4F1WA as he occasionally drops by at DX1MK always breaking in CW mode. All my pre-etched pc-boards were immediately exhausted in due time as more fellow hams scrambled to have one. I'm sure the circuit went to many more Hams who are now enjoying the use of this "Master CPO pro" from THE MAKILING AMATEUR

RADIO SOCIETY (MARS).

Try this YSL (Yari Sa Laguna) project and you will be amazed by its sweet and beautiful tone. It first appeared in the early 90's as a MARS leaflet under the same title and author which served as a homebrew tickler for members. This home brew article contains the expanded text edition.

Mind you, practice makes perfect!.......CW is here to stay in the DX amateur bands!
Happy Home Brewing!
DE DU1ANV … 73's… SK dit dit.

Even in this time of high technology, Morse Code is still the faster mode of communicating compared to Celphone Text Messaging!
.... Max/4F1BYN