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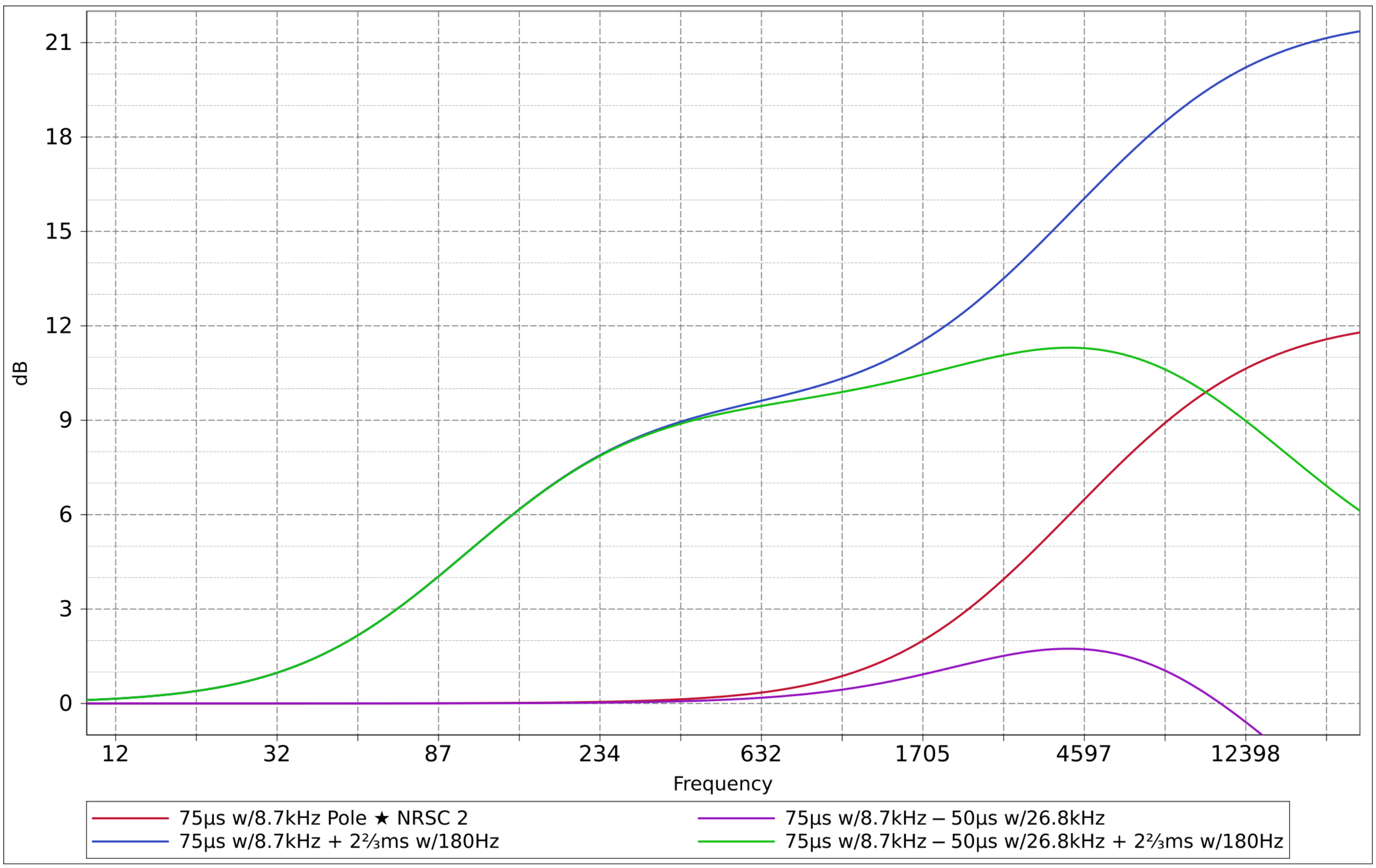
TX 100mW Mono 1680 AM

A Mono 100mW Transmitter on 1680kHz AM

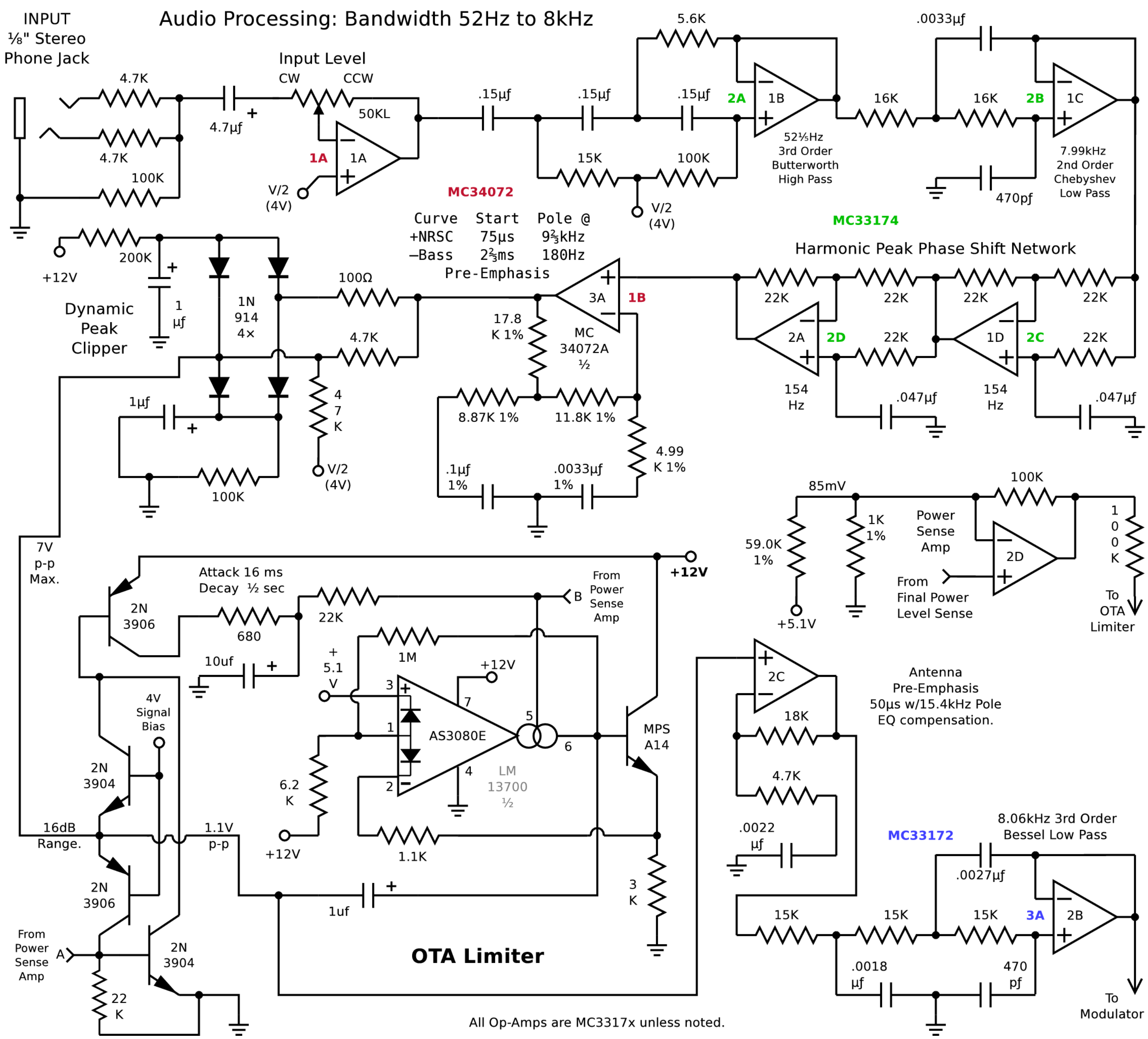
This is presented to demonstrate what can be done to condition the modulating signal to maximize the signal quality during transmission and reception using a maximum of 100mW of input power into the final amplifier. (However, for live speech using an electronic voice compressor, or for music converting to mono, doing multi-band compression with a computer based sound program and storing it in a compressed audio file, and making minimal use of the compressor described here is the optimal arrangement.) A moderate and unique amount of pre-processing is used to take advantage of certain features and limitations of a short antenna (3 meters) and limited power (100mW). Some of it is conventional and found in use in commercial broadcasting, some is a modification of those features to optimize effectiveness for this application, and some are completely new. For **AM Stereo** implementing some of these features especially in non-linear systems like C-QUAM®, Kahn ISB®, or Magnavox PMX® require accurate math processing at the audio level for a clean signal and **DSP** is the only practical way to go. In Mono using a full analog path is fairly straightforward and relatively cheap using off the shelf components.

75µs & 2⅔ms Pre-Emphasis and 50µs De-Emphasis



Pre-processing starts out with an adjustable input gain amp. Next is a 52¼Hz Butterworth 3rd Order High Pass Filter followed by a 8kHz 2nd Order Chebyshev Low Pass Filter and then a Harmonic Peak **P**hase **S**hift **N**etwork which moves the harmonic peaks of of the peaks of their fundamentals reducing peak amplitude without clipping while maintaining loudness. Next is a 3.183kHz (50µs w/26.8kHz pole) De-Emphasis simulating the antenna response for proper limiting. This will be restored after the Dynamic Peak Clipper and Limiter has reduced modulation to ─100% for the frequencies below 3.183kHz (50µs) so the receiver will not see modulations greater than ─100%. The antenna pre-emphasis boost will exceed ─100% but upon leaving the antenna the modulation will not exceed

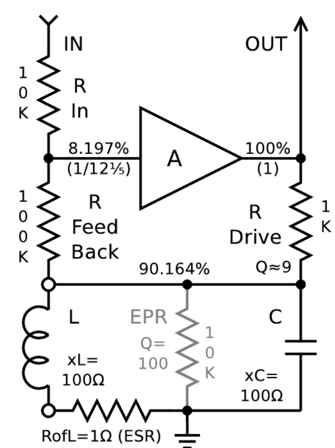
–100% allowing for carrier reduction placing more power in the sidebands. The graph above shows the standard 75µs w/8.7kHz Pole NRSC2 Pre-Emphasis (**Red** curve) along with a 2⅔ms w/180Hz (**Blue** curve with the **Red** curve combined) which reduces bass levels. In music bass program material is the strongest and this EQ reduces bass levels by ⅔ adding a average minimum headroom of 3dB for the higher frequencies with a potential up to 5½dB. This S/N loss for the bass frequencies is much less noticeable than the S/N loss in the higher frequencies and can be compensated for with the proper De-Emphasis EQ or turning up the bass control. The 75µs w/8.7kHz + 2⅔ms w/180Hz –50µs w/26.8kHz (**Green** curve) is what the Clipper/Compressor will process and what the envelope detector in the receiver will mostly see. The **Purple** curve is the NRSC2 75µs w/8.7kHz and the RF/IF receiver response 50µs w/26.8kHz combined without the 2⅔ms w/180Hz bass reduction added. After Clipping and the Limiting the signal peaks have been flattened generating harmonics that need to be removed prior to transmission. Next is the 3.183kHz (50µs w/26.8kHz) Pre-Emphasis response removing the antenna De-Emphasis modeling. Finally an 8kHz 3rd Order Bessel Low Pass Filters is used. The Bessel response has a maximally flat delay filtering out harmonics without producing overshoot. The combination of the two approximates a 5th Order Butterworth Low Pass response. In order to take advantage of the efficiency of a high Q antenna which are typical of



vertical shorts a narrow bandwidth must be maintained but this produces a low fidelity transmission. Reducing the Q to widen the bandwidth reduces transmitted signal strength so using a high Q narrow bandwidth antenna and EQing the modulating signal for a flat response is the way to go. In order for the transmitted signal to obtain the maximum ─100% modulation response at the receivers envelope detector Pre-Emphasis for the antenna response has been compensated for. This requires the signal modulator to exceed ─100% modulation and a four quadrant modulator like a Gilbert Cell is needed. In the left of ths image above are Dynamic Peak Clipper and OTA Limiter. The Clipper is a compound one in that one resistor and two diodes independent of the signal path are used to charge the capacitors defining the attack time and bleeders set the decay time. The signal path is a resistor divider which sets the adjustable headroom and uses the 2nd set of diodes to limit against the charged capacitors. The Limiter input is a 4.7K resistor that clips the signal when it exceeds ~1.1Vp-p by operation of the NPN & PNP emitters as their collectors transmit the clipping current through current mirrors to charge the 22µƒ capacitor in ~33ms while the 22K resistor sets the 2.2t decay time of 1 sec. Selection of these two components allows the adjustment of attack and decay times. The capacitor with the 22K resistor sets the decay time and the capacitor and 680Ω resistor sets the attack time. The 22K also sets the maximum gain of the OTA so the decay time must be set solely by the capacitor. An equilibrium is obtained when the amount of clipping is enough to keep the capacitor charged and activate the OTA Po-Amp to attenuate the signal. The goal is to keep the signal ~1Vp-p maximum so the modulator will not exceed ─100% for receiver compatibility.

The Oscillator (My Current Theory)

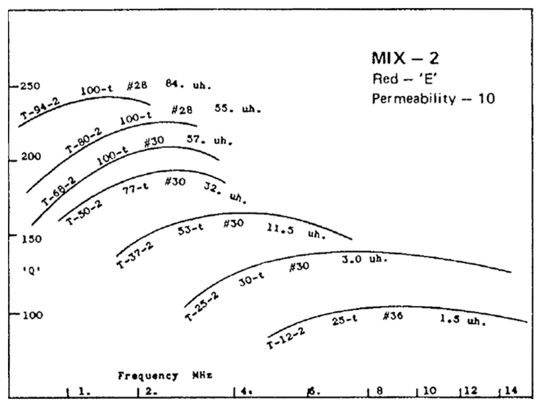
The best carrier oscillator is a quartz crystal. If you have one cut to the the desired frequency then use it. It's easy to build an oscillator with one that is reliable and very stable. That being said, and lacking one, needing to have a custom crystal cut, may not be cheap and turn around time may be slow. The other option is an LC oscillator but careful design is needed for good frequency stability that is low in amplitude and phase noise.



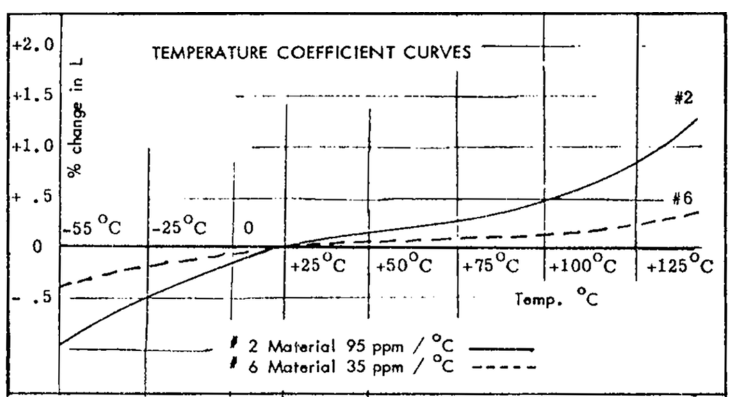
Critical Feedback Model
Regeneration A<12⅕
Oscillator A≥12⅕

The Regenerative Receiver. It is hard to not talk about this when talking about oscillators because it is an oscillator when the regeneration gain is turned up too high. This type of receiver was popular before super-heterodyne was invented. Its operation was simple and positive feedback was used to increase the Q of the tank almost to the point of oscillation. Operating the regeneration control increased the positive feedback and the skill was to turn it up to to increase the Q and narrow the bandwidth to increase selectivity without going into oscillation. Turn it up too high and oscillation would occur. A blip was heard and the received signal was muted. To stop oscillation the control had to be turned down past the point where oscillation started for it to stop, having a hysteresis. It takes more feedback to start the oscillation that to maintain it. It was called regeneration because the signal passed through the band pass many times and each pass narrowed the response but another effect was also at play, negative resistance. In the diagram to the right the LC tank is assumed the be made with perfect theoretical components. An 1Ω resistor is placed in series with the inductor to represent the winding resistance. At resonance where xC=xL=100Ω the 1Ω ESR of the inductor converts to 10K EPR. This RLC tank has a static Q of 100 without the other components added. With A=0 making the output impedance of the amp 1K and the input grounded this represents the full static model. With all this positive resistance loading the LC tank it reduces the Q to ~9. As 'A' increases in value the 1K output impedance is being neutralized with negative resistance and at some point just before critical feedback it ceases to be a load on the tank and only the 10K EPR and the R In + R Feedback of 110K is keeping the Q below 100. As 'A' increases more towards critical feedback the 10K EPR and the 110K will also be neutralized with negative resistance and the Q will begin to rise above 100. In this theoretical model at the critical feedback point all load on the tank disappears, the Q of the LC tank is ∞ and so is its parallel resonance impedance. At the point that the 1K, EPR of 10K and 110K positive resistance loads are neutralized with negative resistance 'A' is inversely equal to the feedback reduction and is at unity gain. When 'A' rises just above unity gain oscillation starts and signal strength rises until the circuit limit is reached. At this point the oscillation can be sustained with less feedback which creates the hysteresis effect. With each pass the signal makes through the amp the signal grows in strength and eventually the output signal is larger than the amp can produce and the output is severely clipped and may resemble a square wave. Some crystal oscillators are made to run this way having the output level limited by the amp with little ill effect however this model does not optimize the benefits of maintaining a just over-unity feedback level for LC versions. Having too much negative resistance has the same detrimental effect on Q as positive resistance and reducing Q reduces the purity of oscillation. What is needed is the right amount of negative resistance over-unity feedback to maintain oscillation with the maximum possible Q. An **A**utomatic **L**evel **C**ontrol that maintains a just over unity feedback and maximized Q has to be designed into the oscillator.

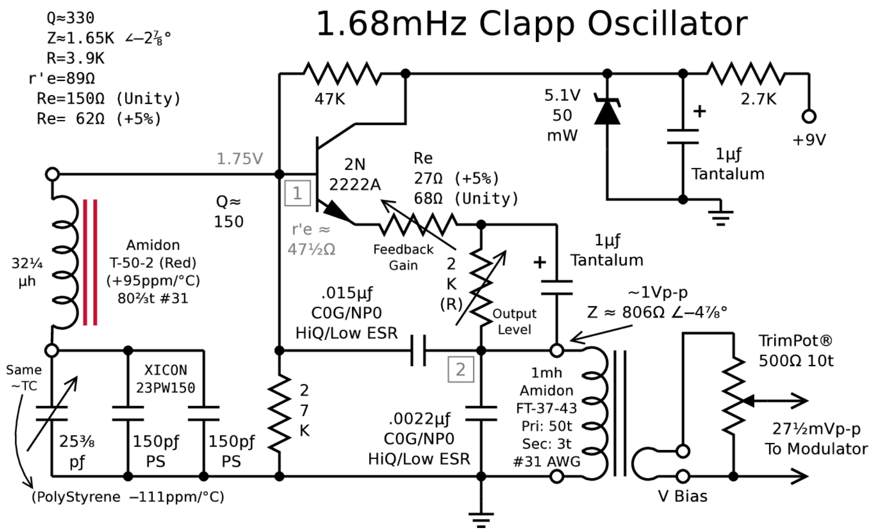
Frequency stability is the other main factor in a good LC oscillator. Choosing high quality resonant components with high Q and combining them in proper balance to neutralize temperature coefficients is a must. The Q limiting factor of many LC oscillators is the inductor as the capacitors used usually have Qs in the 1000s. The kind of oscillator is also important for good stability, one with low phase and amplitude noise so the Clapp oscillator will be used. From some preliminary calculations the size of inductor needed is ~35µh. Fortunately Amidon has some example windings on their cores with the resultant inductance and Q. Using Mix #2 and in the chart to the right on a size 50 core there is a 32µh example with 77 turns of #30. At the desired operating frequency its approximate Q is 180. Adding 4 more turns should get it up to the desired inductance but the next smaller wire #31 is needed and will probably lower the Q by 10 to 170. The capacitors having a Q in the 1000s in combination with the inductor should have a estimated combined Q of ~150. In the analysis this value will be used to calculate the ESR of the inductor and the capacitors pure to simplify analysis. Matching the temperature coefficients to cancel out the drift requires that the total resonant capacitance has an equal but opposite coefficient of the inductor.



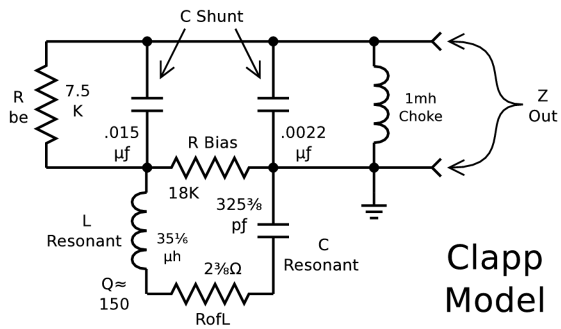
To the right the graph specifies Mix #2 having a +95ppm/°C. The curve is not straight and from 35°C to 75°C this straight line area extrapolates to +55ppm/°C. The slope increases around 25°C so the +95ppm/°C spec. is assumed to be for this temperature. At –25°C it is +125ppm/°C. For practical use a 20°C to 30°C operating range using +95ppm/°C is realistic. Finding a type of capacitor with with the exact same but opposite coefficient is slim. Usually a combination of capacitors with different coefficients are combined in the proper ratio to match the inductor's coefficients. In this Clapp oscillator the resonant capacitance will be polystyrene. One source for for them is XICON and the temperature coefficient graph in the datasheet is a fairly straight line with a slight curve. There is a ½% change over 45°C equating to $-111.\overline{1}$ppm/°C. To make this easy using C0G/NP0 (zero drift) types for the shunt capacitance and adjusting the ratio between the two types the polystyrene's coefficient can be reduced and balanced with the inductor's coefficient. $95/111.\overline{1}$=85½, the polystyrene's reactance needs to be 85½% leaving 14½% for the shunt capacitance. 85½÷14½≈5.9:1 . The shunt capacitors of .015µ*f* & .0022µ*f* in series is 1918⅗p*f* and the needed resonant capacitance is 325⅜p*f*. All of these in series is

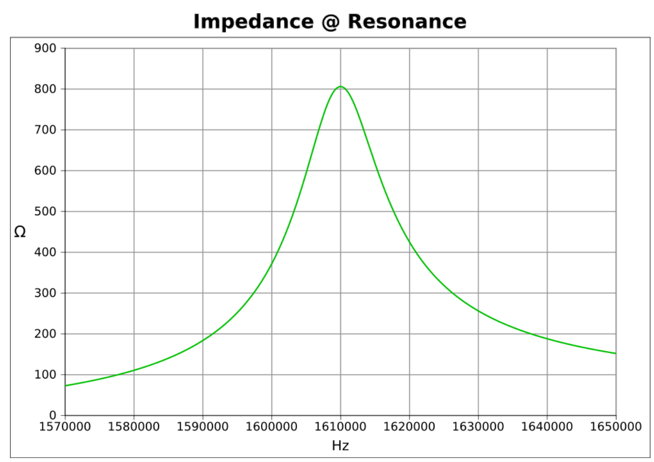


278⅓pƒ and the inductance needed for resonance is 35⅙µh. If the coefficient cancellation is kept to <5ppm/°C then the frequency drift should be kept to within ±20Hz over a ±5°C (68°F to 86°F) range for this frequency. If a wider temperature range is desired then the temperature coefficient of Mix #15 is +190ppm/°C and a straight line from 0°C to 125°C. Using a similar resonant to shunt capacitor ratio the resonant ones would need to be –225ppm/°C with the shunts being C0G/NP0 zero drift types.

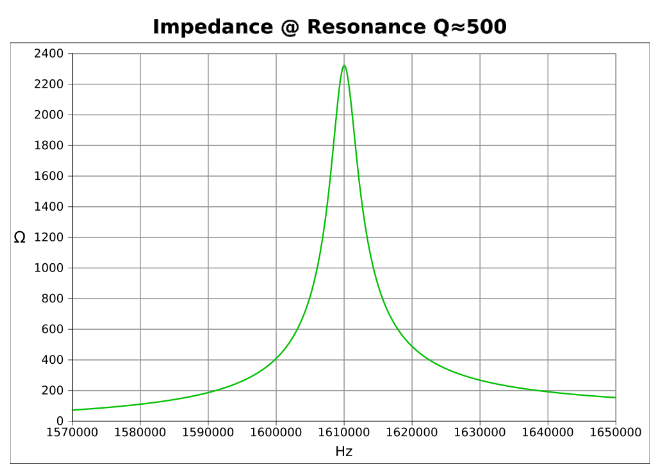


In the top right is the schematic for a Clapp oscillator using a bipolar transistor. If the parts arrangement looks somewhat familiar it is from the ARRL Handbook, referred to as a Colpitts, with some variations. This 1st version was the starting base to develop an analysis model and does not have an **ALC** so it is hard to predict exactly what the real output level will be. In order to determine the necessary amount of feedback the output impedance needs to be calculated and the analysis model to the right is used. To reduce the math complexity only the most critical components are part of this model. Using complex numbers in a spreadsheet and assigning the resistance and reactance to real and imaginary, (r,i) respectively, inductance +i and capacitance -i, and plugging the complex numbers into series and parallel resistance formulas the output impedance was determined over a frequency range and the static response is plotted in a graph to the upper right. It peaks at 806Ω. The shunt capacitance voltage divider between points 1 & 2 is 87⅕%. To have just over-unity gain feedback with the 806Ω output impedance Re + r'e will need to be <118Ω for oscillation to start.

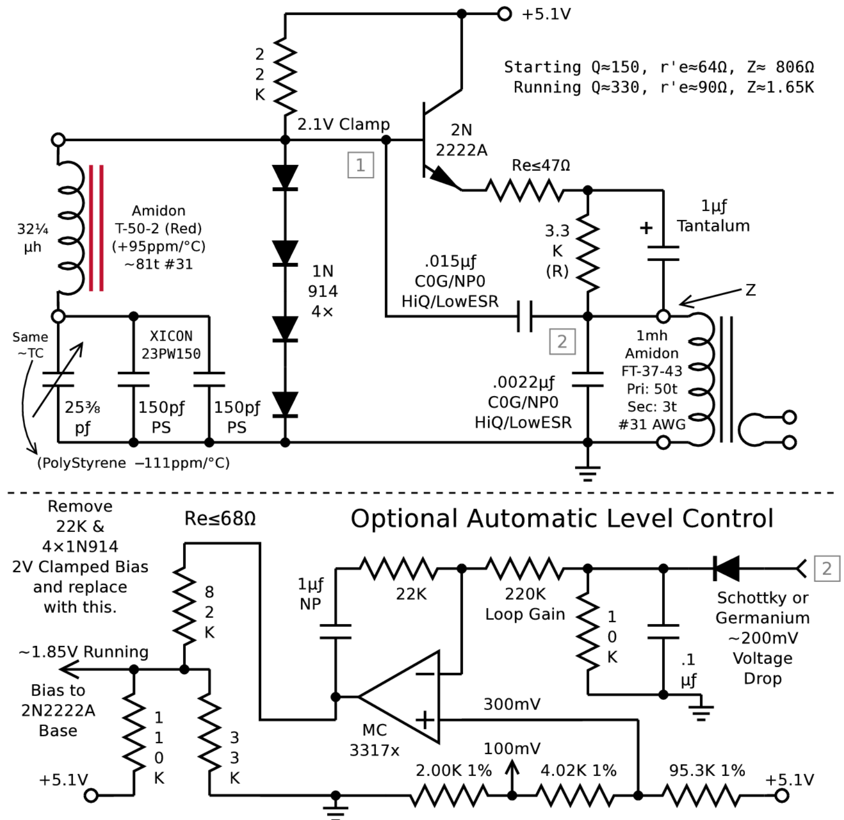




Once oscillation starts the feedback will produce negative resistance which will neutralize the positive resistance. In practical applications it is unrealistic to expect all positive resistance to be neutralized and obtain a Q of ∞ and Z of ∞. The Q limiting factor is the inductor. The minimal contributions to positive resistance are base loading of the transistor, biasing and ESR of the capacitors, and all will be mostly neutralized. The inductor winding resistance accounts for <25% of the Q limitations and will be mostly neutralized also. This leaves the core losses. To be conservative if ⅔ of the core losses can be neutralized



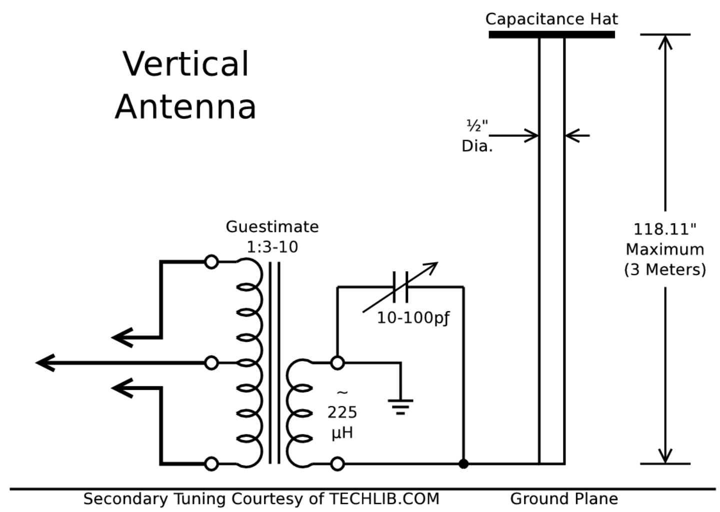
and adding in the other neutralizing factors the running Q could be >500 with a neutralized Z of 2⅓K. This value of output Z has been created by Re + r'e of ~100Ω combined with the initial output Z of ~800Ω to create enough negative resistance needed to produce the necessary feedback for oscillation.



Automatic **L**evel **C**ontrol. This is needed to maintain a constant output level and to keep the oscillator operating in an optimal range with just the right amount of negative resistance over-unity feedback to maximize Q. In the drawing to the right the bias is clamped. This is adapted from the J-FET version of this oscillator described in the ARRL Handbook. Given the differences in biasing of J-FET and bipolar transistors the layout is slightly different but the effect is the same. As the amplitude increases the bias level decreases because the clamped signal reduces the bias voltage. For both types of transistors the reduction in bias voltage reduces the idle current which in turn reduces transistor gain. Lower current also means lower output level for a given output impedance. For the J-FET it operates lower on the trans-conductance curve and for the bipolar r'e increases. For both types of transistors it is hard to determine what the output level will be but on start up the gain is high with enough feedback to start oscillation and as the output level increases the gain reduces to a point of equilibrium where there is just enough negative resistance over-unity feedback to sustain oscillation and operate at a near maximum Q. If tight control of signal output level is desired then in the 2nd ½ of this drawing a PLL style loop amp controlled by the rectified signal level is used to control bias voltage level which effects feedback level. This may not operate at the equilibrium point so at the controlled output level the feedback level may not be optimized. Once output level is set adjustment of Re can be used to obtain the just over-unity feedback to maximize Q.

The Antenna

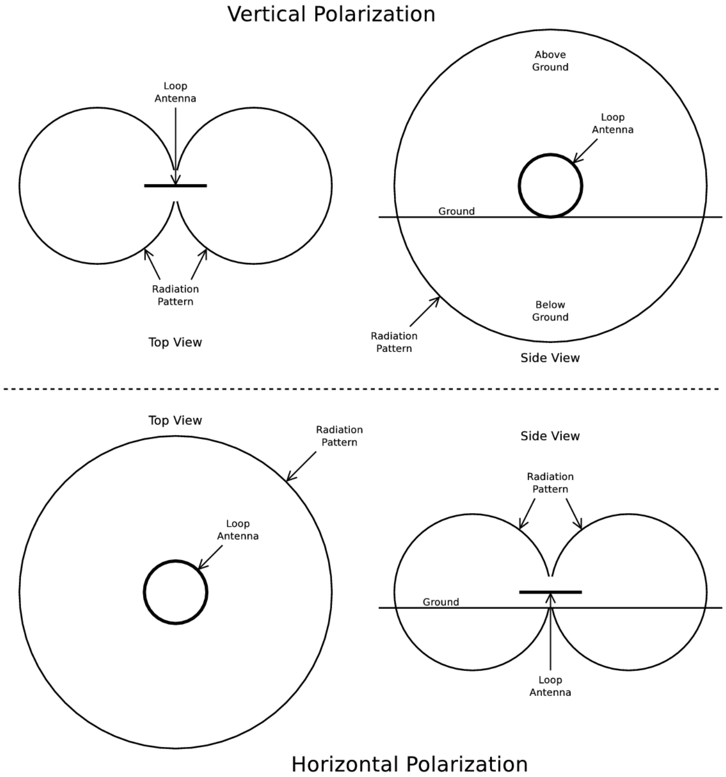
The typical antenna used for 100mW transmission is a short vertical with a loading coil no longer than 3 meters. A good ground plane is needed to maximize load on the amplifier and reach the 100mW limit of input power. The antenna needs the ground plane for reflection to reduce its load impedance. This involves planting enough radials in the ground especially if soil conductivity is poor. If you are lucky to live in a salt marsh and few radials produce excellent ground conductivity then this is about the best situation you can have. Or if there is a big box store that has a corrugated metal support system underneath the roofing material where you may set your transmitter in the middle of it then that would be the 'Bee's Knees'. Under situations like these it is not uncommon to have a usable signal travel 1¼ miles. That being said these situations are hard to



obtain and maintain. A change in weather could affect ground conductivity and thus radiation efficiency if not enough radials are in place. A change from wet to dry when the antenna was tuned for proper loading after a rain and the dry season lowered the radiation efficiency then the final amp would not have enough loading and the signal could be clipped. Or vice-versa where the antenna was tuned for proper loading during the dry season, when the wet season came around the radiation efficiency would increase and overload the final amp and may cause it to draw more than the permitted 100mW of input power. - - - - - For safety it is a good idea to ground the transmitter through a 100K resistor or a 10mh choke to bleed off any static electricity that might accumulate from the high voltage at the top of the antenna. You don't want a Van de Graaff generator that could shock someone or damage equipment.

In balancing power output with the antenna's load resistance in the image above the proper amount of inductance in the transformer's secondary is needed for the loading coil. Using the output transformer's secondary to double as the loading coil is more efficient and transfers power better. To cover the whole AM band 2 to 3 different inductance taps in the secondary along with the 10-100pf trimmer should allow the antenna to be tuned to resonance. After establishing the ground plane and determining the load resistance the proper primary to secondary impedance match must be made which also includes the supply voltage to the finals in the calculations to meet the 100mW power input limit. The class AB amp is the most efficient for linear amplification and the primary of the output transformer is center-tapped for this type. Although an auto-transformer is more efficient it would be a difficult setup for this type of class AB amp.

These issues with a vertical short antenna make it difficult to adapt to the goals of this document. Over on TECHLIB.COM's Personal Radio Station page the use of a loop antenna is described. As the article mentioned its radiation is magnetic and unlike a vertical it cuts through solid objects pretty well, up to the outer limits of the coverage area and nothing much affects its resonance or radiation pattern, well, unless you stick something magnetic in the middle of it like a large piece of ferrite ;-). It does not require a ground plane and small loops are usually considered poor radiators but in this application it is well suited. In the picture the antenna is positioned for vertical polarization and its radiation pattern is similar to a dipole but perpendicular with the two lobes aligned with the plane of the antenna. Perpendicular to the plane of the loop are the null points. The radiation pattern resembles a Static Warp Bubble with the radiation extending up into space as far as it does on each of the lobes. It also extends below ground but depending on soil composition the signal may extend further below ground or be absorbed. If you're not concerned with the ground wave using horizontal polarization may be a better option. Consider this, in space (not time) your signal will be in quadrature, and your signal will be the strongest at all other signal's null point that are vertically polarized. The radiation pattern will also be omni-directional. Your signal's null point will also be vertically polarized greatly reducing the potential for interference to licensed broadcasters. It's like your signal is radiated on a whole other plane of existence. You control the horizontal, they control the vertical ;-). The only requirement for reception is that the receiver's ferrite antenna inside the radio must be positioned vertically



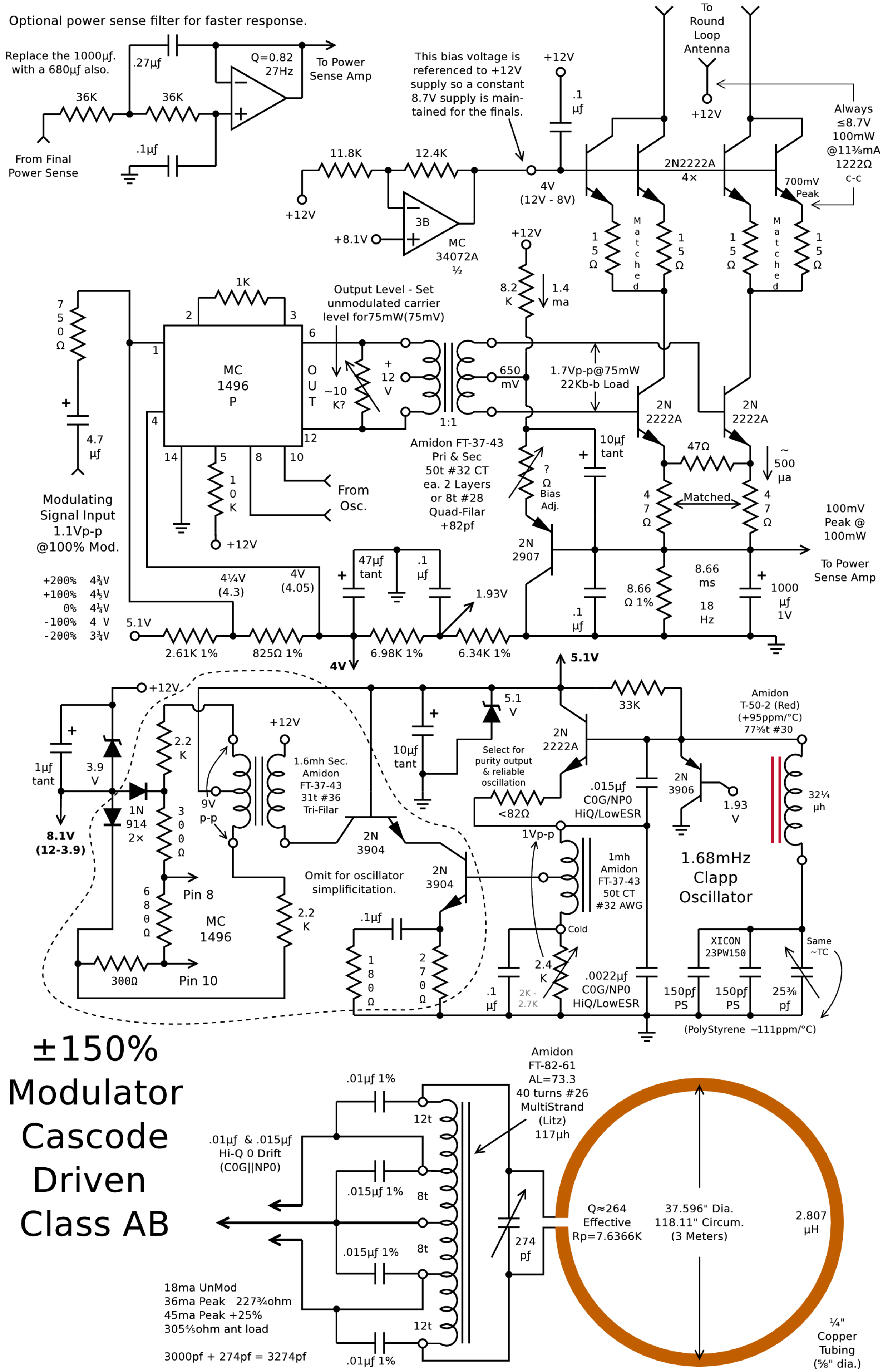
instead of the normal horizontal position. This means placing the radio on on its side in most cases. This also nulls out any signals received that are vertically polarized. The loop antenna pictured and described on the page is made out of ½” copper pipe, is a square 30”×30” O.D. and the inductance he has estimated to be is 2µh but **EEWeb** says 2¼µh, although using 0.889 premeability will produce 2µh. It is usually assumed that for air core inductors the permeability is 1 but it may be less or his calculation is a very rough estimate. With the circle being the shape of the most efficient loop antenna, maximum area for minimum circumference, this is the shape to be used. For bendability using ¼” copper pipe makes it easy to form. After using the online calculator on **EEWeb** to determine the inductance of a round loop made with a ¼” copper pipe with a 3 meter circumference the result is 2.81µh, or 2.64µh for ⅜” pipe, so this is the value that will be used although it may actually be a little different but it is close to inductance of the square version so some adjustments can be made to accommodate resonance. Using a permeability of 0.889 then the inductance for ¼” and ⅜” pipe would be 2½µh and 2.35µh respectively. These inductance values are ballpark figures so actual inductance may not exactly reflect the formula calculations. More info on **Loop Antennas** is here.

The 100mW Final Input Power Limit

The Final will operate from a regulated 8.7V supply. Minus the voltage dropped across the resistors the input power is calculated from the voltage drop across the antenna load and output transistors. To calculate the amount of load needed to reach the 100mW limit the power divided by the voltage will define the average current allowed, 100mW÷8.7V≈11½mA, making average load resistance 8.7V÷11½mA≈757⁹Ω. A Sine wave's average voltage is 2/π or 0.6366 so to get the same amount of current to flow the resistive load would need to be 2×757⁹Ω÷π≈481⅞Ω. An unmodulated carrier is ½ the amplitude of the carrier during +100% modulation so the load resistance would need to be ½ of this, 481⅞Ω÷2≈240⁹Ω. For reasons described and clarified a reduced carrier will be used. The current level of the unmodulated carrier will be reduced by 2½dB and will use 75mW of input power. This requires the antenna load resistance to be increased by 1⅓, 1⅓×240⁹Ω≈**321¼Ω**. The output transistors will need a minimum Vce of ~½V before saturation so the actual load will need to be 302¾Ω. The loop antenna has a very high Q and at 1.68mHz and a ±3.183kHz (±50µs) bandwidth this makes the Q 263⁹. The inductance of the loop is ~2.8µh, the step up output auto-transformer is 117µh and in parallel is 2.741µh. The **E**ffective **P**arallel **R**esistance for the desired bandwidth is 7636⅝Ω. If the Q is greater then De-Q it with a resistor. If it's less and can't be increased then determine to Q and calculate bandwidth/2 for the audio corner frequency for the Antenna EQ. If this Q is a dramatic reduction from the desired Q then the finals have the potential to draw more power necessary for the same voltage drop. For maximum efficiency the proper tap ratio will need to be determined for best input power to output radiated energy and components properly selected. The voltage step up from the final outputs to the loop antenna is 1:5. It is defined by the .015µƒ & .01µƒ capacitive divider and the auto-transformer is tapped at the same ratio. Just the capacitive divider could have been used for the step up alone but a center-tapped choke is still needed to supply the power to the transistors so why not also use it to do some of the lifting as an auto-transformer. With the 1:5 voltage step up the impedance step down to the output transistors is 25:1 making the load on the transistors **305½Ω**, close enough.

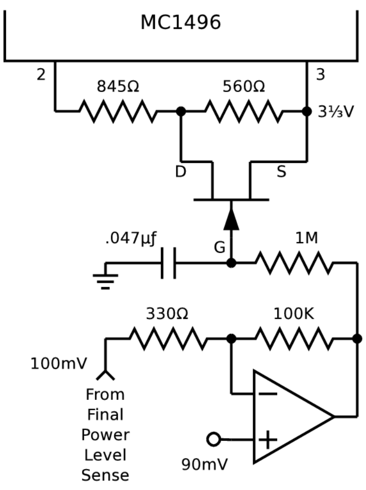
The Modulator & Final Output

The modulator is a MC1496 Gilbert Cell running with carrier inserted by a DC bias. The modulator is operated to ~±37% of peak clipping level for 100% modulation for frequencies below 3.183kHz (50µs) leaving a 6dB headroom. Insert a 200Hz tone into the input at a level where the compressor is engaged and limiting the amplitude. Vary the input level to see if the compressed signal varies. Turn up the input to the point of clipping, ~7V, by the voltage swing limitations of the prior input stages and then back off some till no clipping occurs. This is probably the maximum level the limiter will see. With and unmodulated carrier adjust the MC1496 output via the ~10K? shunt on the output tank until 75mV (75mW) is obtained on the power sense resistor. Trim the ?Ω bias resistor on the finals to


±150% Modulator Cascode Driven Class AB
Optional power sense filter for faster response.
Replace the 1000µf. with a 680µf also.
.27µf
Q=0.82
27Hz
To Power Sense Amp
36K
36K
.1µf
From Final Power Sense
This bias voltage is referenced to +12V supply so a constant 8.7V supply is maintained for the finals.
+12V
.1 µf
To Round Loop Antenna
Always ≤8.7V 100mW @11⅜mA 1222Ω c-c
11.8K
12.4K
3B
MC 34072A ½
+8.1V
4V (12V - 8V)
2N2222A 4×
700mV Peak
15Ω
Matched
1K
750Ω
MC 1496 P
OUT
~10 K?
+ 12 V
650 mV
1:1
Output Level - Set unmodulated carrier level for75mW(75mV)
8.2 K
1.4 ma
1.7Vp-p@75mW 22Kb-b Load
2N 2222A
Amidon FT-37-43 Pri & Sec 50t #32 CT ea. 2 Layers or 8t #28 Quad-Filar +82pf
10µf tant
? Ω Bias Adj.
47Ω
~ 500 µa
47Ω
Matched
100mV Peak @ 100mW
To Power Sense Amp
4.7 µf
Modulating Signal Input 1.1Vp-p @100% Mod.
10K
+12V
From Osc.
2N 2907
8.66 ms
18 Hz
8.66 Ω 1%
1000 µf 1V
+200% 4¾V
+100% 4½V
0% 4¼V
-100% 4 V
-200% 3¾V
4¼V (4.3)
4V (4.05)
47µf tant
.1 µf
1.93V
5.1V
2.61K 1%
825Ω 1%
6.98K 1%
6.34K 1%
4V
5.1V
+12V
1µf tant
3.9 V
8.1V (12-3.9)
1N 914 2×
2.2 K
300Ω
9V p-p
1.6mh Sec. Amidon FT-37-43 31t #36 Tri-Filar
10µf tant
5.1 V
Select for purity output & reliable oscillation
<82Ω
2N 2222A
33K
.015µf C0G/NP0 HiQ/LowESR
2N 3906
1.93 V
Amidon T-50-2 (Red) (+95ppm/°C) 77⅝t #30
32¼ µh
1.68mHz Clapp Oscillator
1Vp-p
1mh Amidon FT-37-43 50t CT #32 AWG
Cold
2N 3904
2N 3904
Omit for oscillator simplificitation.
Pin 8
680Ω
MC 1496
300Ω
Pin 10
2.2 K
.1µf
180Ω
270Ω
.1 µf
2.4 K
2K - 2.7K
.0022µf C0G/NP0 HiQ/LowESR
XICON 23PW150
150pf PS
150pf PS
25⅜ pf
Same ~TC
(PolyStyrene −111ppm/°C)
Amidon FT-82-61 AL=73.3 40 turns #26 MultiStrand (Litz) 117µh
.01µf 1%
12t
.01µf & .015µf Hi-Q 0 Drift (C0G||NP0)
.015µf 1%
8t
.015µf 1%
8t
12t
.01µf 1%
274 pf
Q≈264 Effective Rp=7.6366K
37.596" Dia. 118.11" Circum. (3 Meters)
2.807 µH
¼" Copper Tubing (⅝" dia.)
18ma UnMod
36ma Peak 227¾ohm
45ma Peak +25%
305⅘ohm ant load
3000pf + 274pf = 3274pf

eliminate crossover distortion. It is necessary to use a center tapped 470µh choke with a 1K resistive load to properly observe any distortion on the scope. The high Q antenna will also filter out any RF harmonics but any distortion can make the –100% modulation transition point rough.

Alternate Gain Reduction

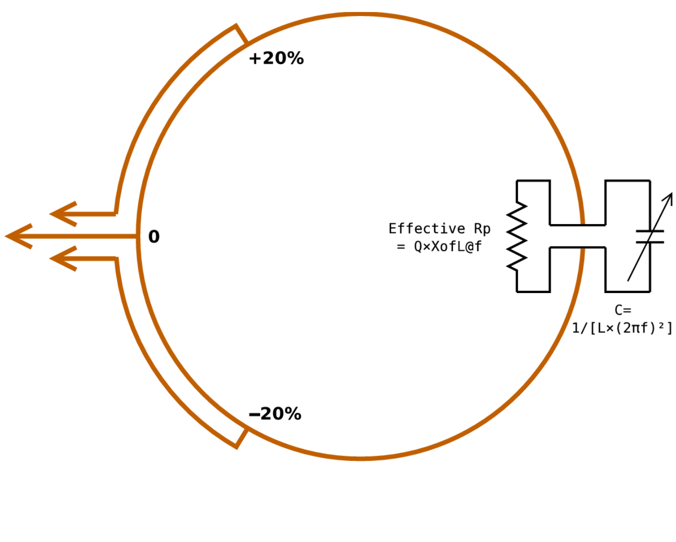


The disadvantage in reducing the modulating signal alone when the power level limit is approached via the limiter is that this would appear as a volume reduction at the receiver. By reducing the carrier level also thus maintaining the same modulation level but reducing the power output this can be compensated for by the receiver's AGC. The best place to apply this is on the MC1496's 'Re', pins 2 & 3, of the modulating signal input. Increasing its value reduces gain on both carrier and modulating signal. By adding 680Ω to the 1K will provide an ~4½dB reduction. During normal operation the 680Ω is shunted providing a ~1K impedance between the emitters. During periods of power reduction the variable resistance is increased to the needed reduction. The quick solution would be to use a Vactrol but since these are hard to obtain using a J-FET as a variable resistor is another solution. The J-FET will need a low ON resistance and a pinch off voltage of <3V, maybe a selected 2N5434. This arrangement is best for small signals. It is estimated that the signal seen by the FET during its mid point of operation would be ~150mVp-p and only for momentary periods so any distortion that is generated should be low and hopefully unnoticeable. For good AGC tracking modulations have been filtered out above 3⅖Hz. There may be better solutions that may be distortion free but also may be more complex.

Oscillator Simplification

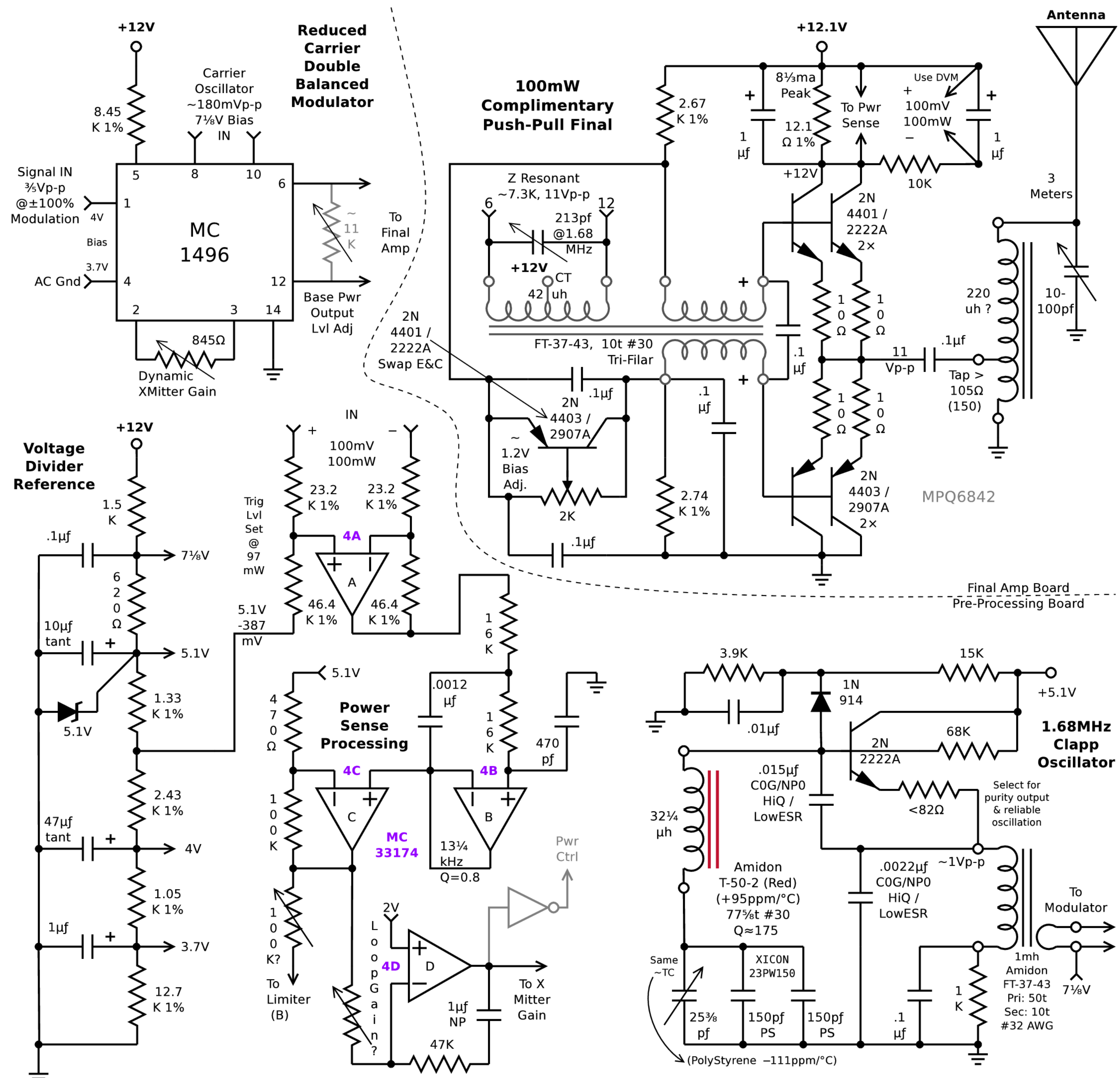
The oscillator section uses an elaborate linearizing circuit for for the MC1496 to greatly reduce harmonic output. This also maximizes transmitter output since any signal other than a sine wave contains harmonics which consume energy that is shunted and not radiated. This is probably overkill for Part 15 since out of band suppression only needs to be ≥20dB below unmodulated carrier. The antenna Q of 264 offers up to 48dB of out of band suppression which is more than adequate. For economy and simplicity taking the oscillator signal off of the 1mh output choke is possible. Omit oscillator parts: 2×2N3904, 180Ω, 0.1µf, 270Ω, 1.6mh transformer, 2×2.2K, 2×300Ω, 680Ω, 2×1N914. Bias between the 3.9V & 5.1V zeners with a 1.2K resistor. Wind the choke with 50 turns primary and 10 turns secondary. Place the secondary at the cold end of the choke, connect it to pins 8 & 10 of the MC1496 and bias the cold end to 8.1V (3.9V zener). For better biasing of the MC1496 oscillator port use a 4.3V instead of a 3.9V zener since the 1N914s aren't used and bias them with a 1K instead of a 1.2K. This also changes the final's biasing amp Vref from 8.1V to 7.7V and the change for the voltage divider from 11.8K to 12.4K and 12.4K to 10.7K.

Alternate Antenna Setup – This is much simpler and more economical than the one described previously. It maybe more efficient too. It could be constructed using a flat copper ribbon/strip on a wooden form. The width of the ribbon could be chosen to produce the desired Q omitting the need for any shunt resistor for Q control. The tap point can easily be selected to produce the desired loading impedance on the final amp to provide maximum energy transfer. The best approach to this would require good antenna design knowledge though.

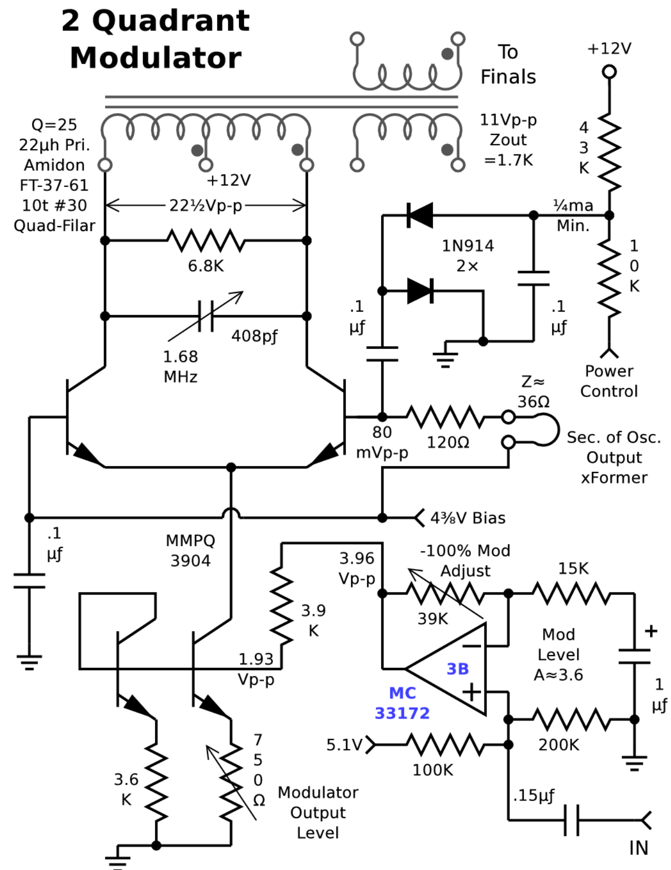


100mW 3 Meter Vertical Antenna Transmitter

The drawing below contains a modulator, oscillator, final amp and power sensing circuits designed to be used with the pre-processing on page 4. Since the output is a source follower and not a current output the antenna pre-emphasis is not needed. The design of the loading coil is not provided as many variables can affect the criteria. If the modulating bandwidth is no wider than ½ the antenna bandwidth then tap the coil for 105Ω impedance and run the final to ~95mW, power level control unnecessary. If the modulating bandwidth is wider than ½ of the high Q antenna bandwidth then try these impedance taps: 131Ω@80mW, 150Ω@70mW, 175Ω@60mW, 210Ω@50mW. Proper use of a top hat and loading coil design, **diamond**  **wound** preferably with Litz wire, is crucial in realizing a narrow bandwidth to take advantage of the efficiency of a high Q antenna.

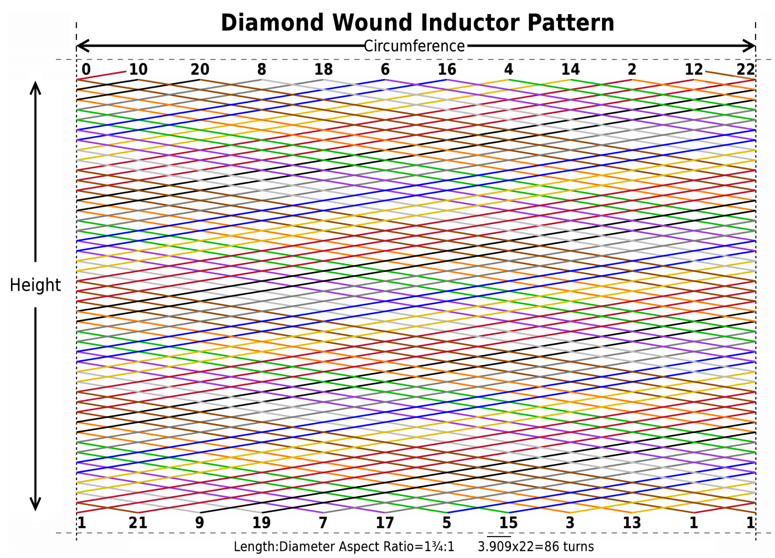


Since the finals low impedance output addresses antenna equalization and negative modulation does not exceed –100% for receiver IF bandwidth compensation the need for modulations greater than this provided by the MC1496 are unnecessary. This custom designed modulator is better suited for the setup on page 13. Its better drive capability for the finals provides better immunity from impedance changes caused by the antenna load.



Modification of the voltage divider is as follows: replace the 1.5K & 620Ω with a 2.2K and omit the associated .1µʃ capacitor, replace the 3.16K with 1.91K, 1.05K with 1.27K, 12.7K with 13.7K, omit the 1µʃ capacitor, move the 47µʃ between the 1.27K & 13.7K for the 4V reference and the 4⅜V reference is between the 1.91K & 1.27K.

To the right is a diamond winding pattern that can be scaled to the desired size for an antenna loading coil. The aspect ratio is fixed at 1¾:1 unless the height and width D.P.I. are set to different values. Setting the print dpi to 300 will yield a 4⅗" length coil that is 2⅝" in diameter. Using the single layer coil formula yields ~220uh of inductance. 86 turns of #15 will fit in a single layer so the inductance estimation should be fair. Each number is a tap that is 1 coil length in winding that is 3.909 turns for a total of 86 turns. Rescaling the size of the bobbin along with the aspect ratio will yield different inductance values. The circumference is 2470 pixels so set the print dpi to to match that of the bobbin.



Copy pattern to clipboard and paste into image editor.

You should access to Part 15 Rules on the FCC website. A quick rundown of a Cliff Notes version of the most important issues are: The input power into the final amp must not exceed a continuous average of 100mW, The antenna must be ≤3 meters in length including the coax lead and/or grounding, Part 15 transmissions must not cause harmful interference to any radio frequency transmission and/or device that operates under rules other than Part 15 that has a protected emission mask under those other rules, Emissions outside the AM band must be suppressed to ≥20dB below the unmodulated carrier. There are other less critical requirements not listed here to be met. It is the responsibility of the user that [he|she|it] comply with the law regarding Part 15 transmission particularly § 15.219 . Obtaining a full copy of the **Part 15 Rules** and carefully reviewing them is highly recommended. At some point in time in the future when the rules become available, again, a full copy may be appended to the end of this document. This document does not intentionally condone or encourage the operation of a Part 15 transmitter outside these rules. It is written for educational purposes and care has been taken to try to present information in a way that complies with the rules.