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Magic Box
Super AM
On/Off
Signal Strength
×10 kHz
60 70 80 90 100 110 120 130 140 150 160 170
STEREO
TUNED
Local /DX
Bass
Low Filter Pull
Treble
High Filter Pull
Volume
Loudness Pull
10kHz Notch Pull
Tuning

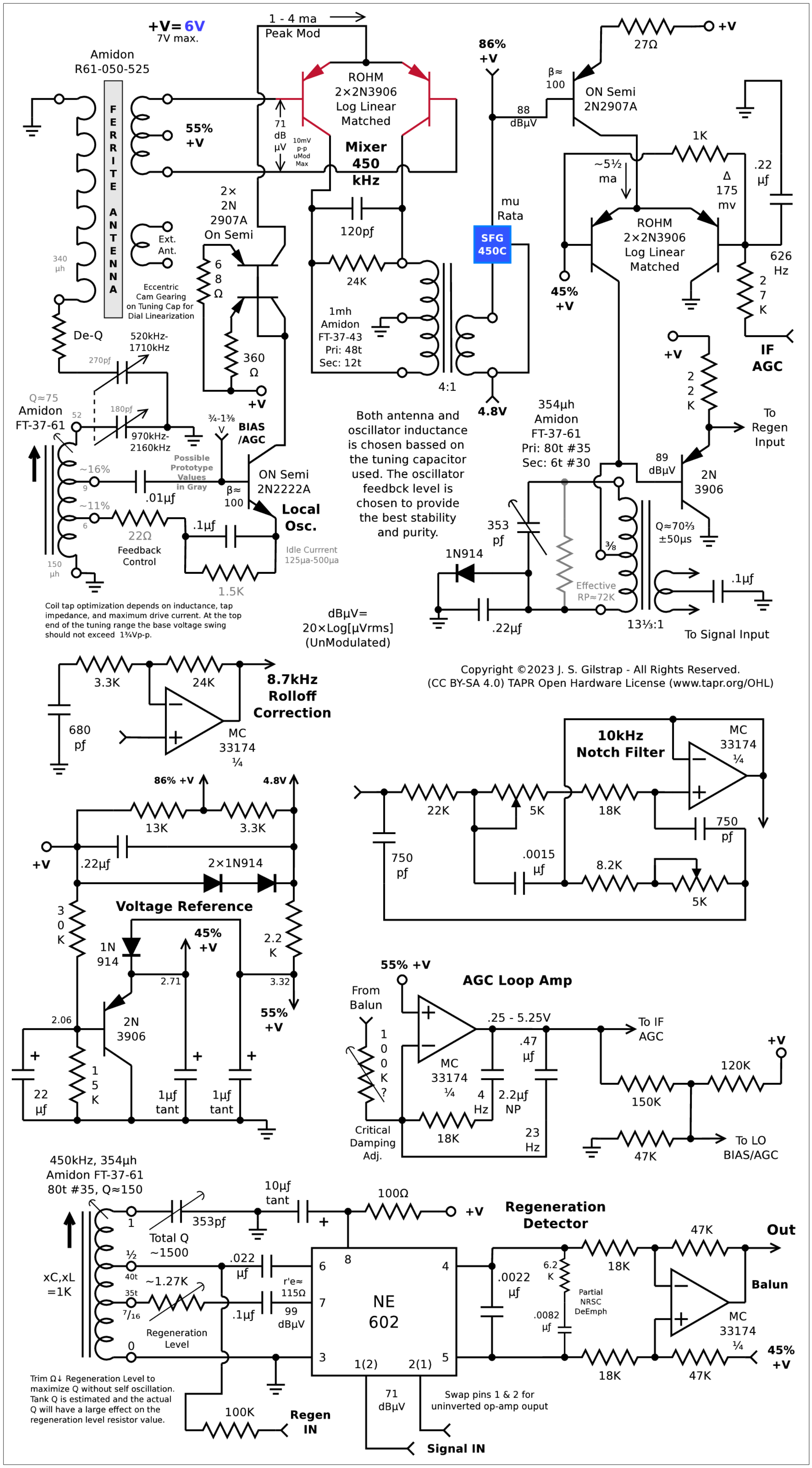
MagicBox™

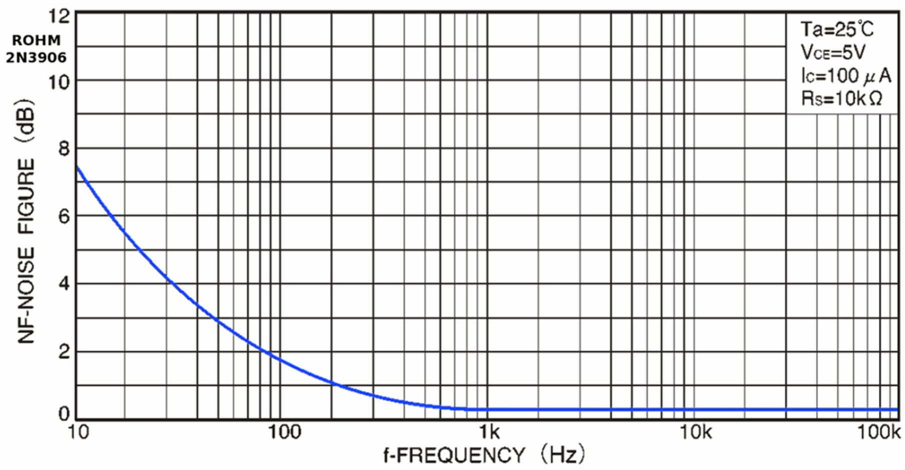
Super AM

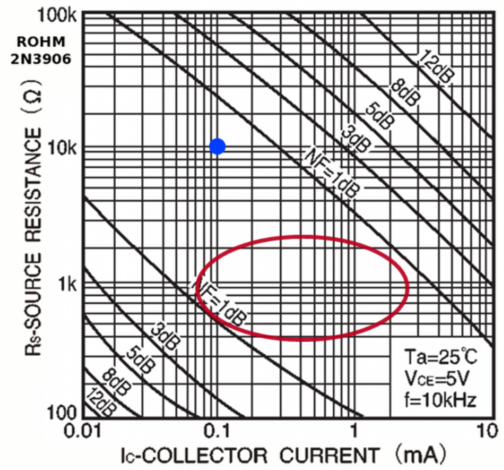
Box O.D. 8”H×6”W×6”D
Inside Volume 225in³
¼” Dense MDF
(Formaldehyde Free)
2 Ports @100Hz
¾” dia. PVC/20
5⅕cm Long, 2.35cm I.D.
–3@84, 0dB@100, +2⅔@150

To the left is most of the schematic. The antenna is a ferrite loop stick and the coil should be wound over most of the rod with Litz wire to maximize Q, and preferably basket woven. Hopefully the Q will be high in the ±5kHz range and stay fairly constant across the tuning range. This should be high enough for good selection and image rejection on DX signals. For strong signals De-Qing the antenna to ±12½kHz with a series resistor on the tank will reduce image rejection performance but this is a minimum issue with good signal strength during daytime hours. At wide bandwidth / minimum Q the response should be fairly flat out to ±10kHz and down to –3dB at ±12½kHz max. A user adjustable pot of 100ΩA provides variable Local/DX Bandwidth/Selectivity.

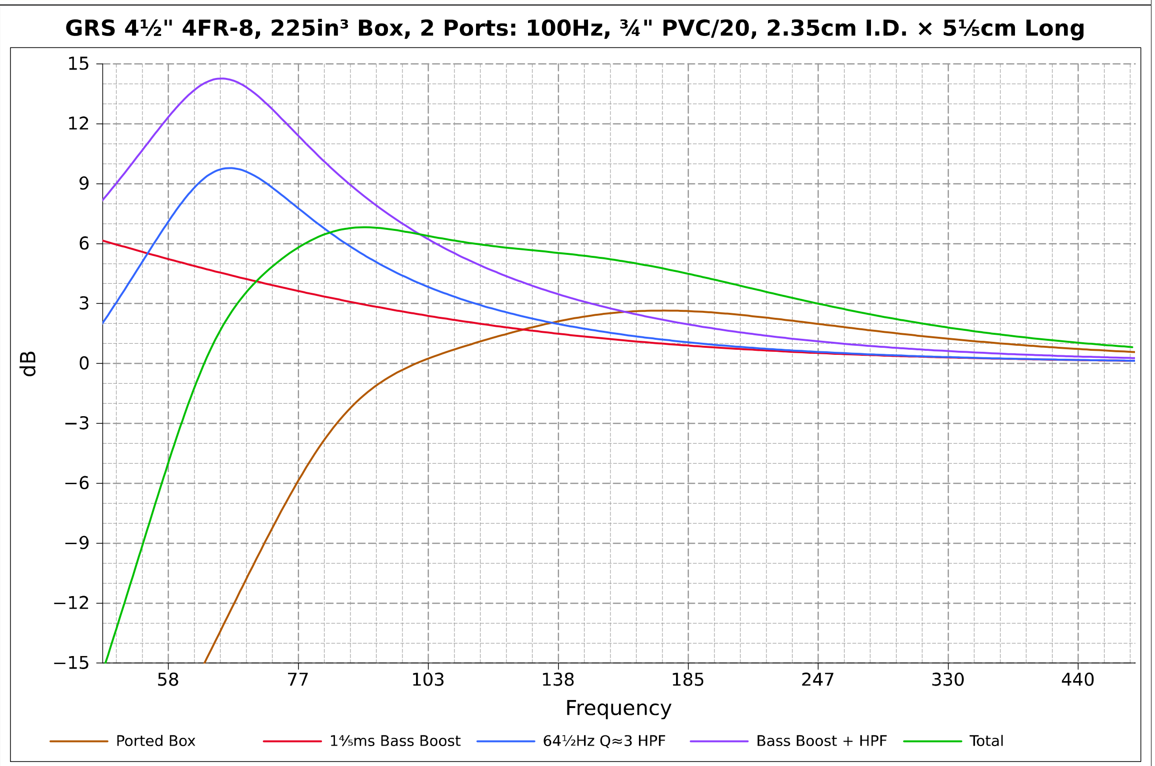
The input stage is a differential pair and unlike a single transistor in which its max input level is 60dBµV a differential pair can handle 74dBµV before distorting, 29mVp-p max imum modulation, that's a 14dB advantage. Like a single input transistor it is also the mixer but not the oscillator. Oscillator input is fed into the emitters but is balanced balanced so it





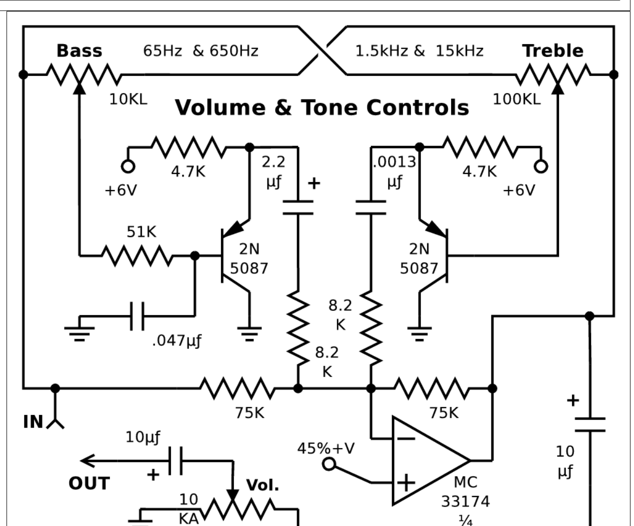


does not appear in the output, only RF & IF which are at a much lower level than the oscillator level. A 2N3906 has a good but not impressive Noise Figure but the **ROHM** units do with a ⅓dB NF starting at 1kHz and extends to 100kHz, as shown above. If this continues for another 1⅓ decade then this is probably the best you can get compared to most other transistors. The **RED** oval is the region where it will mostly operate.

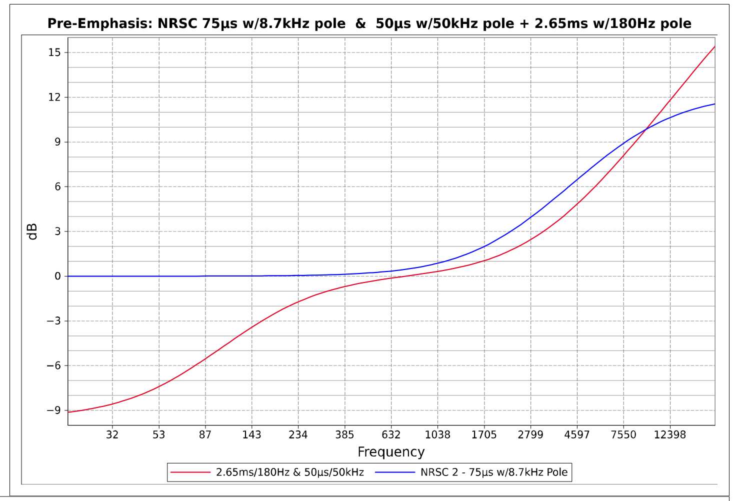


The oscillator is fed through a current mirror and is also a current multiplier which allows the oscillator to operate at optimal current levels. It is possible to feed the oscillator directly if the supply voltage was higher but at 6V this provides the best overall solution.

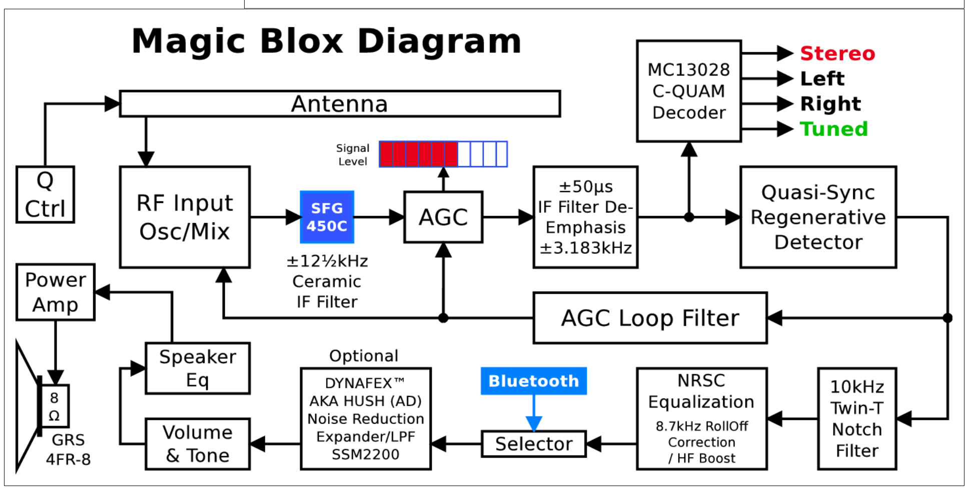
The balanced mixer output is fed into an IF transformer and the secondary feeds a ±12½kHz ceramic filter. Its output feeds the AGC amp that uses a differential pair which varies the current division between the two thus providing a variable gain control. Its output fees a high Q tank which performs a ±50µs de-emphasis (±3.183kHz). This is advantageous for envelope detectors since wide bandwidths under marginal conditions causes the detector to greatly degrade. This signal also feeds the MC13028 AM Stereo Decoder, which also uses envelope detection, and for best separation must be precisely tuned. It will not be perfect but will only produce negligible separation loss.



The rest of the de-emphasis is done after detection to produce the final NRSC 75µs w/8.7kHz pole response. It would be ideal to use a ±75µs (±2.122kHz) IF response but the tank Q would be ~110 and much harder to realize. With ±50µs the Q is ~71 and easier to obtain with available components. While the Quasi-Sync™ regeneration detector will perform similar to a true synchronous detector with wide bandwidths this produces a 12dB/Oct. sideband attenuation above ±50µs (±3.183kHz) offering improved BFO protection. If the regeneration amp has a bandwidth of ±150Hz then its response at ±10kHz is –36.35dB. For the ±3.183kHz bandwidth its response at 10kHz is –9.91dB. This is a total attenuation of –46.26dB offering very good BFO protection from adjacent channel carriers. However co-channel interference will depend on the capture ratio of the detector since the switch mode operation of the upper transistors in the Gilbert cell limits the signal. In the U.S. 75µs is popular for audio but in other countries 50µs is used. 50µs also produces an ~10dB response like the NRSC emphasis curve, only the 2-3kHz corner difference range exists. Adding a Bass de-emphasis of 2.65ms w/180Hz pole will add more headroom for the rest of the signal. Reducing Bass levels in transmission is of little consequence since they are less critical and degradation near the carrier and is well protected. The 50µs & 2.65ms w/180Hz pole curve would be a better standard to adopt, shown in the graph to the right.



Adding to the NRSC equalization block in the receiver some high frequency equalization will be necessary to produce a flat –3dB@12½kHz response. Given the antenna bandwidth in wide mode and the ceramic filter attenuation a boost up to +6dB may be necessary. A 12½kHz Chebyshev low pass filter with a Q of 2 can be used. Frequency response testing may be necessary to get it accurate.

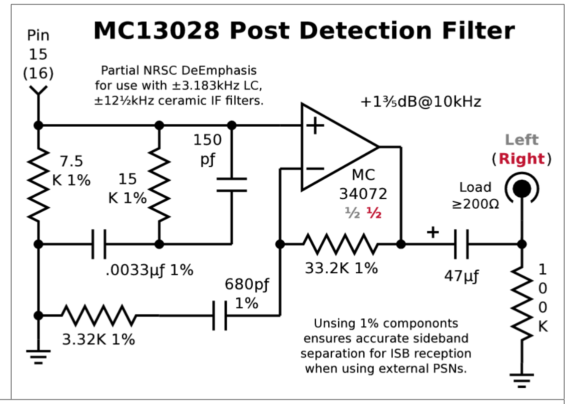


A portable speaker box with **Bluetooth** for connecting phones, tablets, or computers would be a benefit so adding this increases versatility.

In the 80's many car radios came with **DNR®**, a dynamic low lass filter, that provided noise reduction. Back then **DYNAFEX™** also produced the **SSM2200** chip that combined ~1¼ expansion with the this type of filter which provided up to 30dB of noise reduction. Today this circuit can be found in the **A**nalog **D**evices chip **SSM2000** called the **HUSH Stereo Noise Reduction System**. It appears that **AD** may have bought out DYNAFEX and provides a dual channel version but may not make the single channel one now. This kind of noise reduction is ideal for AM since the broadcast signal is usually highly compressed and could stand expansion levels >1¼ applied at the receiver.

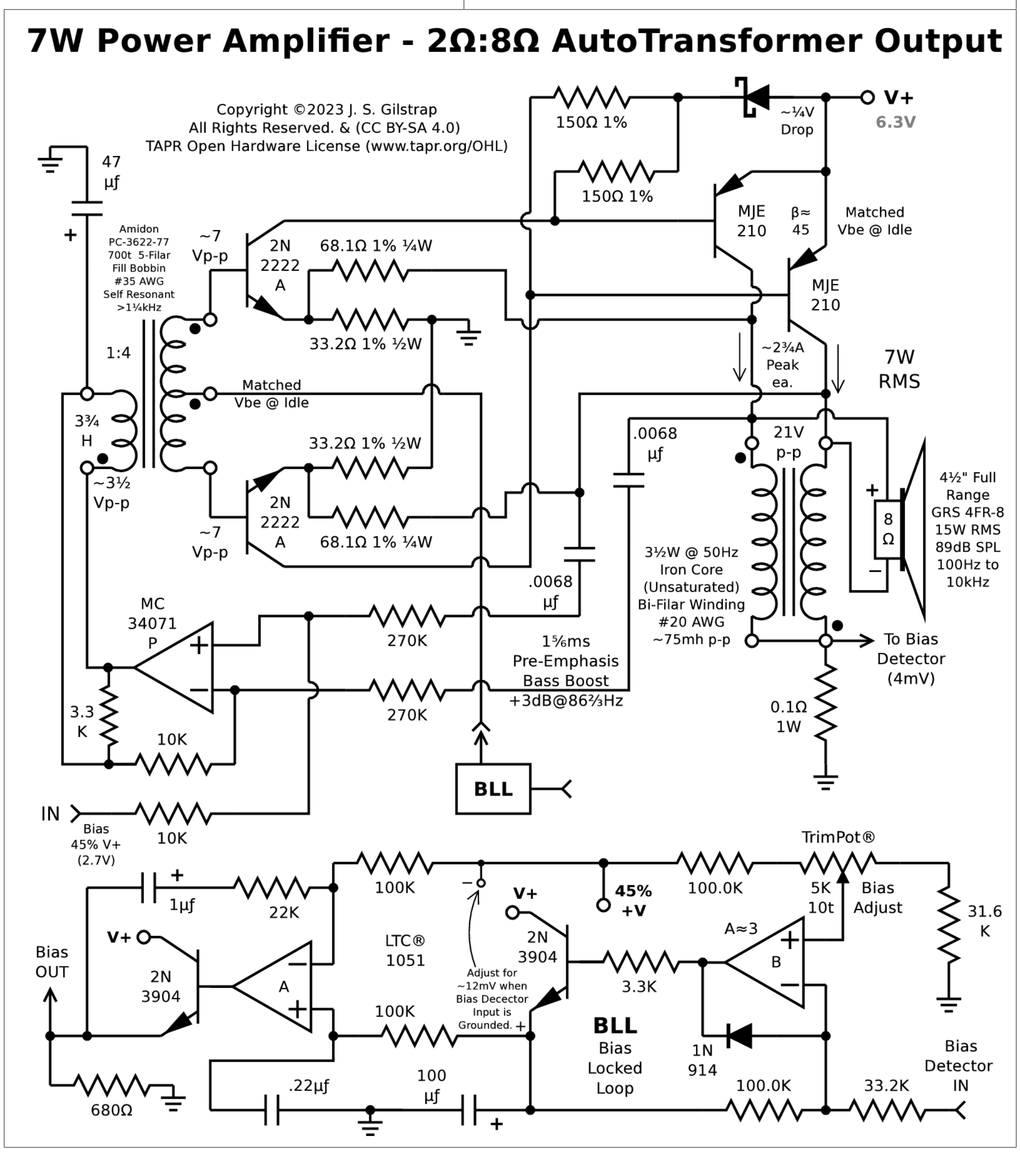
The output amp uses a step up auto-transformer to produce the power from a 6V supply. This setup transforms the amplifier's impedance of 2Ω to the speakers 8Ω to get to this output level. The only other way to get this level of power output is to use a 2Ω speaker driven by a balanced output. To get 7W output the amp should use a 7V supply.

The available speaker chosen is the **GRS 4FR-8 4½"** and it is rated at 15W RMS with a frequency response of 100Hz – 10kHz and an 89dB SPL. It is touted as a replacement for the **Pioneer A11EC80-02F** which has a greater frequency response of 60Hz – 15kHz with a 96dB SPL. The Pioneer unit looks like a clone of the old **CTS 4½"** midrange that was used in the **Bose 901** speakers in a low Ω version. The Pioneer unit looks like the better one to use or even the old CTS ones if either are available. Regardless of the one used all need equalization to flatten the response just like the Bose 901 and its custom equalizer to match. For the GRS a 1⅚ms Bass Boost in the power amp's feedback and a 64½Hz Q≈3 Chebyshev CVCS High Pass Filter (2×0.15µƒ, 2.7K, 100K) should work in this ported WinISD designed box and at the high end a 12⅘kHz Q≈4⅙ Chebyshev CVCS Low Pass Filter (2×22K, 4.7nƒ, 68pf) is a starting point. This probably won't produce a perfectly flat response and more sophisticated eq setup can be fabricated along with port tuning for the low end. Real in box speaker testing is the only way to effectively flatten the response through equalization.



Except for maybe using an LC tank instead of a ceramic resonator for the VCO on the MC13028 all other peripheral components are defaults specified in the datasheet. Forced Stereo is accomplished by pulling up the pilot I detector pin (9) to ~1¼V (1.2-1.5) via a 1K resistor. Forced Mono is accomplished by shunting the Blend pin (8) to Gnd. This also re-initializes the PLL/Decoder into a Fast Lock mode which reduces Stereo acquisition time when released.

The battery supply should be 4×1½V Alkaline D Cells for a 6V supply however alkaline cells will only be good for low to medium listening levels because of their higher internal resistance. Lower resistance units like rechargeable GelCells or Lithium D cells will provide the current needed with little voltage drop for high power use. An external 7V regulated supply sourced from 120VAC or a car's 12V system is probably the best.



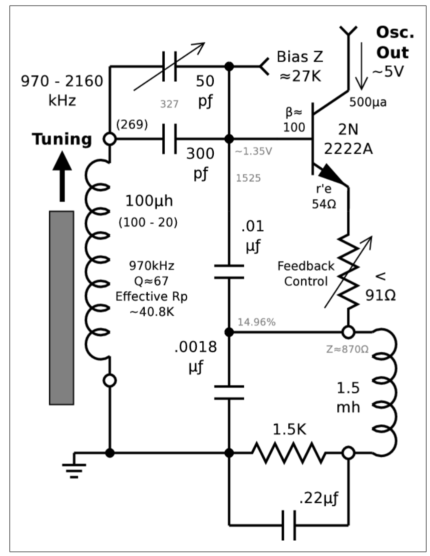
In the power amp the Amidon driver transformer is driven by a single op-amp. Using a dual op-amp setup for a balanced drive with an optimized winding ratio of 1:2½ will provide better headroom with greater drive capacity.

Since there are no emitter resistors on the output transistors maintaining proper bias is critical. Since the transformer center tap is connected to ground through a resistor a voltage sense is taken and amplified with a precision op-amp and then envelope detected for the minimum current dips. A loop amp is used along with a voltage reference to constantly track the bias level and provide correction if necessary.

Local Oscillator – For a single frequency oscillator the design is more straightforward. Apply enough feedback (negative–resistance/conductance) to overcome positive resistance for a gain >1 and you will have oscillation. VFOs used in super heterodyne receivers especially for the MW band the tuning range will vary by a factor of almost 2¼. For a slug tuned VFO the parallel tank resistance stays constant along with the same bandwidth while the Q increases proportionally with frequency which makes VFO circuit design easier. In a capacitive tuned VFO, keeping the bandwidth the same, the parallel tank resistance increases by the square in the change of frequency, a factor of almost 5. Also the proportional increase in Q in relation to frequency tends to level out it and limits the change of resistance and feedback needed. This is good as it makes design a little easier but the increase in bandwidth may reduce purity some.

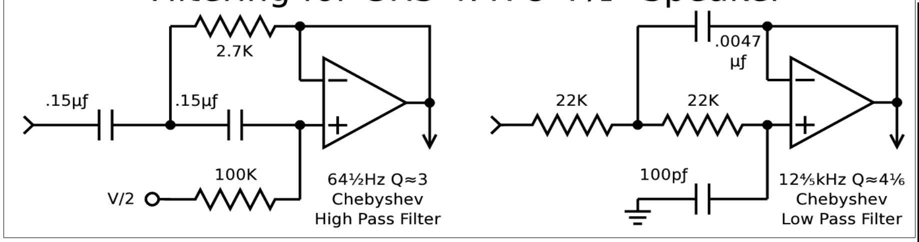
A current controlled variable input supply produces a proportional modulated output current level which in this circuit controls mixer gain for the AGC. However for capacitive tuned setups an increase in supply current increases Vp-p levels and from low to high frequency the increase is mostly proportional. At the high end and maximum AGC current maximum p-p levels will occur and must be limited to work within circuit boundaries. The amount of feedback needed is greater at the low end so supplying just enough at minimum current levels is critical and at the top end its more than adequate for oscillation and can be overkill if not chosen properly. It may be possible to use a small inductor to decrease feedback as frequency increases to partially compensate for this. The **E**mitter to feedback tap ratio should be chosen to produce enough load to match the drive current provided by the transistor for operation within circuit p-p boundaries. The tap connected to the **B**ase should be ~18% greater that the other to supply an over unity gain for reliable feedback. Feedback can then be reduced via a resistor for optimization. This 18% value is for fixed gain single frequency but for VFO+Gain this could need to be as high as 45%.

The modulated **C**ollector current output is applied to the mixer via a current mirror multiplier. In the schematic there are prototype numbers in **gray** but this is just a starting point. The goal is to provide the best AGC gain over the tuning range and still maintain good oscillator performance. Currently it is setup for 12dB. It is controlled by the resistive divider network fed by the AGC amp which supplies the variable bias voltage to the oscillator. Changing the three resistors will change the range and peak bias to the oscillator.



Capacitive tuned VFOs are more difficult to make operate properly over a wide range where a slug tuned unit keeps its impedance fairly constant over the range and insures consistent feedback. A hybrid setup of a capacitive tuned antenna and a slug tuned oscillator is best for compact antenna size. To the right is an example of a slug tuned Clapp oscillator that can offer a stable impedance profile throughout the tuning range.

Filtering for GRS 4FR-8 4½" Speaker



Dark Themed Version ϕ 15½W×15½D×25H (cm)

GRS 4½" 4FR-8, 4.8L Box, 2 Ports: 80Hz, ¾" PVC/20, 2.35cm I.D. × 6½cm Long