THE FM BUG/TRANSMITTER

There are thousands if not millions of mono FM transmitter guides over the internet, and i constructed one with their help (for a recreation Studying those complicated equations of QM),and improved upon it with some cheap junk. My friend suggested me to write this, I'm not an expert in this field, but im writing what I know, and what I understand of the marvellous 'bug'!!!

So whats an FM signal?

In poormans words: We hear a voice the various tones syllables due to the variation of the amplitude,frequency of the word spoken.These variations can be transmitted in RF regions by the means of Frequency modulation,i.e. Transmission of input signal by variation of the frequency of the wave.Thus is FM,there is a carrier wave together with a signal wave which changes the frequency of the carrier wave by small amounts proportional to the changes in amplitude of the input signal.

Modulation index(m) of the wave is the maximum deviation of the frequency($m = \partial\omega / \omega$)where w is the carrier frequency and delta w is change in frequency.

The Basic Design:

The fm transmitter consists of three stages, the first is an CE amplifier, which takes the input from the microphone and amplifies the signal which is then fed into the second stage which consists of an oscillator circuit. The oscillator circuit is ideally consist of two stages, one the modulation circuit and the next the fundamental frequency circuit. But in the compact design we merge these two circuits into one by a clever modification of the circuit and using the fact that the junction capacitance of the transistor at RF is enough to modulate the frequency, but this has a drawback, we cant have control on the modulation index of the transmitted wave. However who wants a amateur to build a class transmitter?

The third stage separates the antenna from the oscillator circuit s.t the changes in capacitances nearby the transmitter doesn't affect much of the frequency of the oscillator. The third stage can also be integrated to power amplifier, to increase the output power and the range of the transmitted signal.

**The resistance Rm provides the necessary current to the electrets microphone, an electrets microphone does not generate an ac signal, but distorts the input dc signal according the signal received by it.

The Stage CE amplifier(Approximate analysis):

The basic circuit is a <u>self-bias,voltage divider network</u> that amplifies the input signal(which is Audio frequency(AF),so this transistor can be normal AF type) from the microphone and feeds the output to the oscillator circuit.This configuration has stability against temperature change and changes in value of hfe etc,so if you replace a dead(burnt!!) transistor with a similar one, your circuit still works!

There are certain circuit parameters we need to know before continuing, certain specifications

for the transistor we are using.Get hold of on meter or something to measure the hfe(or short-circuit ac current gain) of the transistor. The dc gain consider to be the same almost...(i.e.β)
[I hope the notations are not too fuzzy :) c stands for collector. e stands for emitter, b stands for base]

- The gain of the the amplifier is determined by

Av=hfe*Rc/hie --1

where hie is the input impedance of the transistor and is heavily dependent on the value of Ic

hie=(26+2.6Ic)*hfe/Ic --2

Appling KVL(kirchoffs law) to the output circuit,we get

Vcc=IcRc+Vce+IeRe [Ie=Ic]

Re=(Vcc-Vce)/Ic-Rc --3

Ic and Vce must be so chosen st the product of the two the power dissipated is less th1an the maximum power allowed almost much less than 1/50 th of the value.
To make the gain high enough Rc must be chosen high(1),but if that is the case then Vce must be small and Ic must be small(from 3) otherwise Re will turn out -ve.So the DC operating point is set at round Ic=1 mA
if hfe=120
then hie=3500 ohm
if the gain is designed at 120 then Rc from (1) is 3.5k
therefore from (3) we get Re=1k [considering Vce=1V,Vcc=5.6V]
The stability factor is given by
S= β(1+Rb/Re)/(β+Rb/Re)
S is chosen = β/20
this gives ***Rb=[(β-20)/19]*Re ---4***
where ***Rb=R1||R2=R1R2/(R1+R2)***
from input circuit we get Vbb=IbRb+0.7+IcRe [Vbb=thevenin Equavlent voltage]

=Ic[Rb/ β+Re]+0.7 --5

now ***R1=Rb*Vcc/Vbb*** --6

R2=Rb/(1-Vbb/Vcc)

going to numerical:
Rb=5.2k
Vbb=1.7V
R1=17k
R2=7.6k

Now the capacitors, Human voice (of VF) is in the range of 300-3000Hz,so our amplifier attunes all the signal below 300 hz(f1) frequency and passes on the rest to the amplifier. This is done by C0.
$1/(2\pi f1C0)=hie||R1||R2$
Or ***C0=1/(2nf1 * hie||R1||R2)*** ---7
putting values its approximately=260 nF(near value)
Ce is chosen so as to bypass the Ac signal and st it doesnt disupte the DC balancing of the transistor
this can be in general chosen as large as possible,for VF.The minimum value is set by the

equation

$$\underline{Ce=(1+hie)/(2*3.14*f1*hie)}$$

=18uF

The Oscillator:(Q2,RF transistor)

There are several designs for Oscillator circuits, The Wein,hartley,Colpitts,Clapp,etc etc...Some are suitable for Rf frequency some for AF frequency ...The clapp is generally a modification of colpitts,which gives a sligitly better frequency stability,but that is not much of our use because we will use a crystal anyhow to provide fair amount of frequency stabilty to our circuit.here I use Colpitts design.

The transistor biasing is done by Rb.

If we fix the current in the oscillator circuit by say Ic=30 mA(I prefer it a bit high,for better oscillations),
Ib=30/hfe=.15mA,Vce=3V(active region)
Therefore ***Re=(Vcc-Vce)/Ic=100 ohms approx***

Rb=(Vcc-.7)/Ib=33k ohms approx

For RF frequency oscillations, we need very small capacitors and inductor values
say we fix the inductor value to 1 uH,i.e approx 5 turns of a wire approx 4-5mm in diameter then for 70MHz the value of C will be

f=$\underline{1/2*3.14*\sqrt{LC}}$ gives C <5pF.
Here C is the series combination of C1 and C2(remember C adds in reciprocal for series!)

The capacitance is divided,to form a positive feedback network and a gain network ,such that the sustained oscillations are possible.Originally in colpitts design the required condition for phase matching and Barkhausens condition(gain*feedback=1)

As far as I understand ,the positive feedback occurs through Cc hence it is important ,it provides a positive feedback path (via the power rails,urgh!!) for the oscialltor,the minimum value can be chosen from the relation

$$\underline{1/2*3.14*80000000*Cc=Rc} \qquad \text{--8}$$

Here modulation is achieved by connecting the junction of the two capacitors to the collector end of transistor, such that the transistor capacitance (talked before), changes the frequency slightly to achieve frequency modulation.The varcap is used the change the oscillator frequency.

Cs1 is the seperator capacitor,which blocks Dc to the base of oscillator

This design have a frequency drift problem,i.e the frequency drifts with time,to fix this i needed a crystal oscillator...but lo!
I didnt have a crystal oscillator ready at hand,and I didnt want to alter the design much,So i took an old china digital watch,which had a crystal which had a frequency of 32KHz

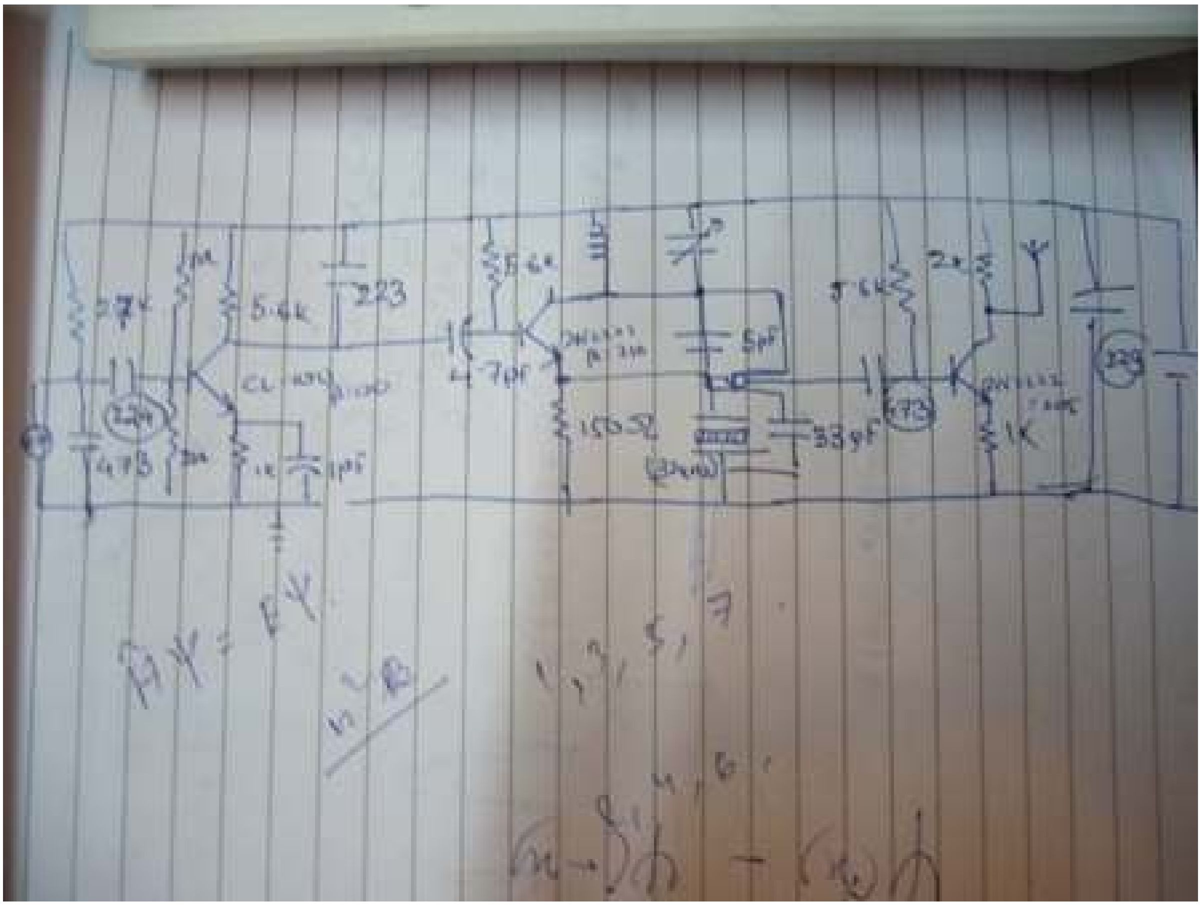
approx.(yes every cheap digital watch has that)!and i wanted it to fix the frequency! so with the crystal i injected a capacitance between the two capacitors,now for every 27^{th} cycle of the original oscillation the frequency is corrected by the oscillator.The capacitor across the crystal smoothens the effect.

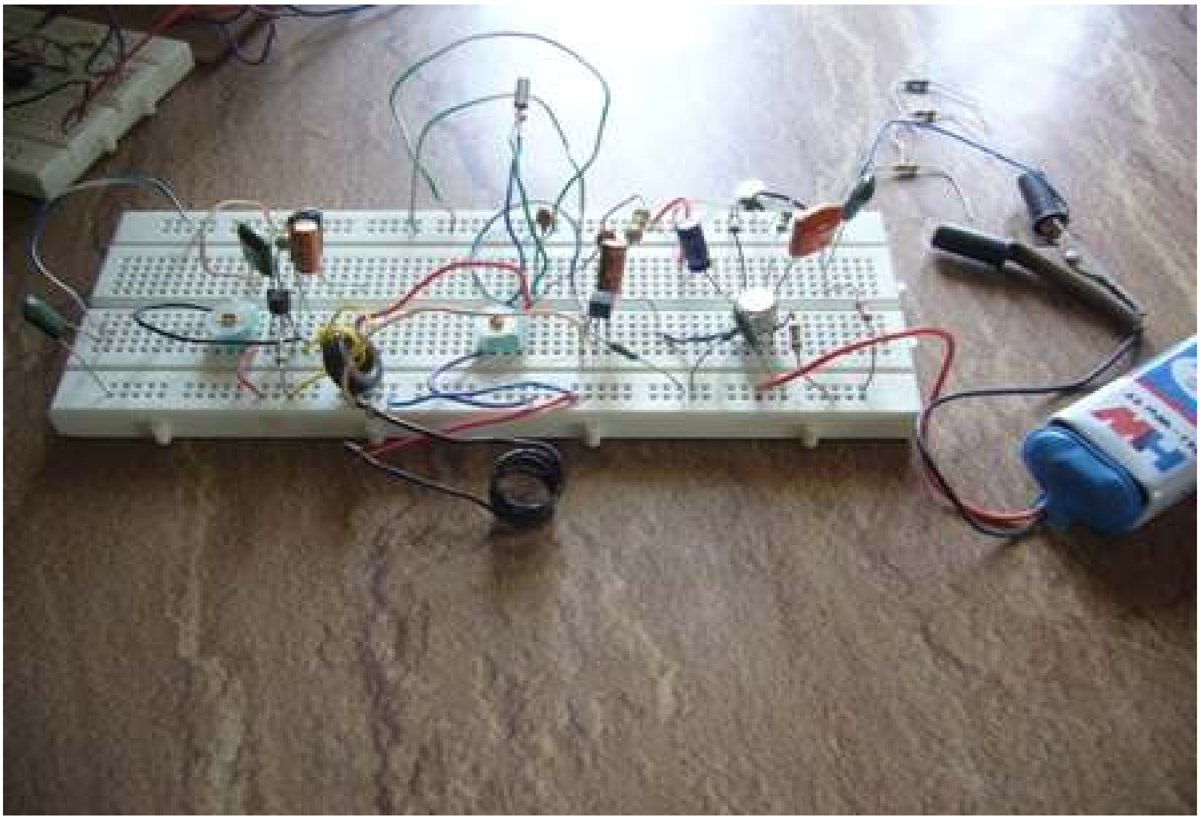
The last stage is a power amplifier,if you dont want to transmit long range you can omit this stage alltogether,or make a simple transistor biasing and feed it with input from output of oscillator,preferablly the transistor is driven from an unregulated power supply.And draw the output from collector junction!For discussions about power amplifier refer internet.

The zener and Rs forms a voltage regulated supply for oscillator,otherwise the frequency with drift with change in output from battery.
If the power rating of zener is Pmax then
$Rs=(Vin-Vz)*Vz/Pmax=100ohms$

I hope this article helps to all the amatures like me who wants to design the bug,and at the same time understand it and its principles,and write down some numbers for it.O I forgot to mention,this bug is strictly mono!!! So don’t expect quality sound! And yes,the frequency tunes to slightly different values everytime you switch off/on!
This article may not be totally error free,as I said Im not an expert in this so suggestions are greatly welcome.

A.Kundu.





The 1st figure shows the ckt diag.Do not read the written values.The last stage is the power amplifer,and was not constructed in the bottom fig.
The bottom fig is the breadboard realisation.It is photographed 180 degrees out of phase with the above!

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