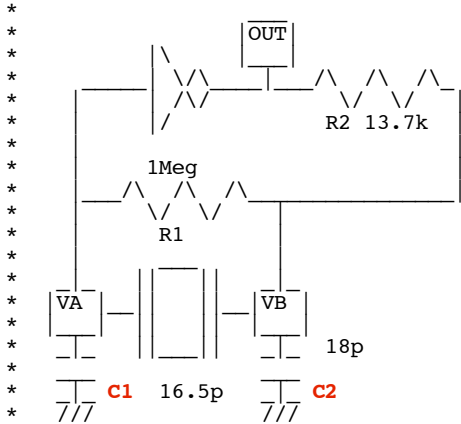


**\*=====Free\_Running\_VCO\_CRYSTAL\_OSC=====**

Crystals are often used in a mode where the output frequency is adjustable. In this application the external capacitor **C1** and **C2** form a PI network with the crystal. The size of **C1** can be adjusted to change the frequency.

**\*=====An Adjustable\_Crystal\_Oscillator=====**

OneMegCrystalReal

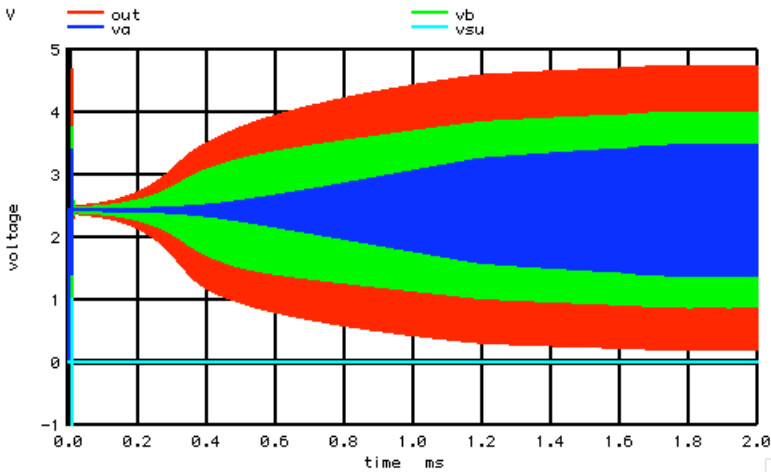


It might be convenient to bias up the capacitor with the expected steady state voltages. And sometimes adding a start up glitch might help

**\*=====Crystal\_Oscillator=====**

```

*.OPTIONS GMIN=1e-18 METHOD=gear ABSTOL=1e-18 TEMP=27 srcsteps = 1 gminsteps = 1
VCC      VCC      0      DC      5
XCRY1    VA      VB      XCRYST
XINV      VA      OUT     VCC      INV_R
XINV4     VREF    VREF    VCC      INV_R
VSU     VSU     0      PWL    ( 0 0 10u 0 10.25u 1 10.75u -1 11u 0 ) DC 0
R1        VA      OUT     1meg
R2        OUT     VB      13.7k
C1        VA      VSU     16.5p    IC=2.42868
C2        VB      0      18.0p    IC=2.42868
    
```



Typical MOS models are being used for the inverters.

**\*=====Real\_Inverter=====**

```

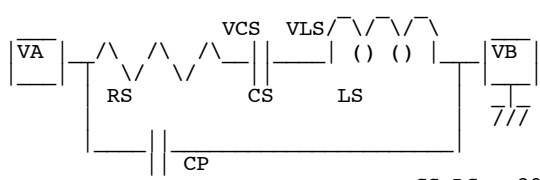
.SUBCKT INV_R IN OUT VCC
MN1 OUT IN 0 NMOSC W=30u L=1u
MP1 OUT IN VCC VCC PMOSC W=90u L=1u
C1 OUT 0 1p
.ENDS INV_R
*
*
* INV_R
*
    
```



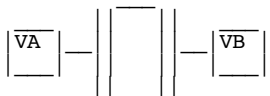
```

RS      VA      VCS      340
CS      VCS      VLS      7f
LS      VLS      VB       3.5
CP      VA      VB       .03pf
.ENDS   XCRYST

```



CS LS = 29.97meg @ 885Gohms



```

* Freq          Mode  L1      C1      R1      C0      Q
* 1 MHz         fund  3.5H   0.007pf 340    3pf    64679

```

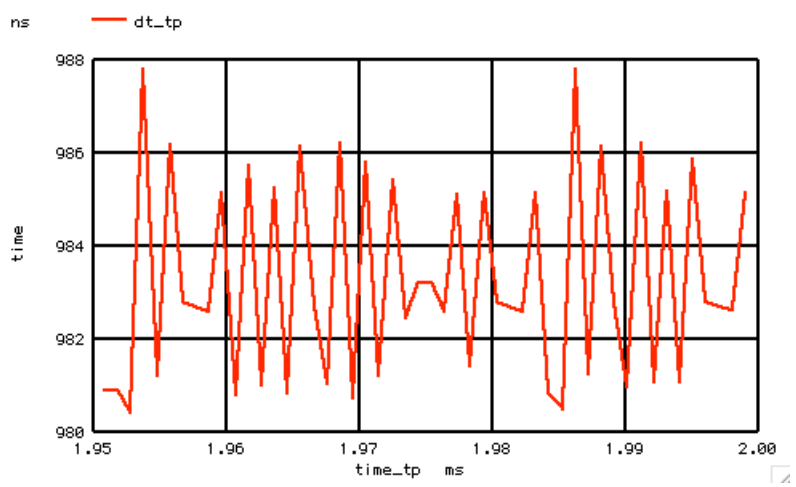
**The last 50 transitions of the oscillator are the most accurate.**

```

=====Process Output Arrays=====
let      Numb_Pt= length(out)
compose  time_tp start = 0 stop = 49 step =1
compose  dt_tp  start = 0 stop = 49 step =1
=====Look at Last 50 edges=====
let      i = Numb_Pt-2
let      n = 0
while    (n < 50)
if       ( out[i]-2.5 >= 0 & out[i-1] -2.5 <= 0)
let      tp = time[i]
let      time_tp[n]=tp
* echo   $&n - $&tp
let      n=n+1
endif
let i=i-1
endwhile
=====Find and Plot periods=====
let      i = 0
repeat   49
let      dt_tp[i] = -time_tp[i+1]+time_tp[i]
let      i=i+1
endrepeat
let      dt_tp[49] =dt_tp[48]
plot     dt_tp vs time_tp

```

**The time delay between the last 50 transitions are calculated and are plotted below versus time.**



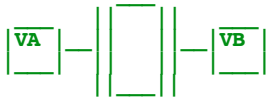
```

=====Print Frequency=====
print    mean(1/dt_tp)
.endc

```

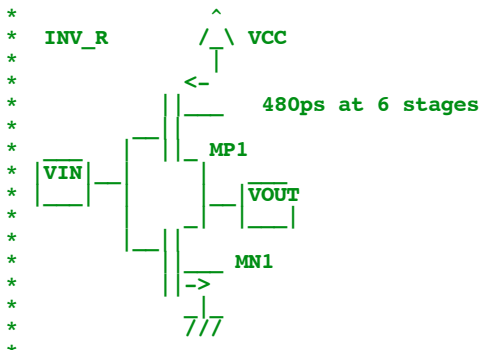






```
* Freq      Mode  L1    C1      R1    C0      Q
* 1 MHz     fund  3.5H  0.007pf 340    3pf    64679
```

```
=====Real Inverter=====
.SUBCKT INV_R IN OUT VCC
MN1 OUT IN 0 0 NMOSC W=30u L=1u
MP1 OUT IN VCC VCC PMOSC W=90u L=1u
C1 OUT 0 1p
.ENDS INV_R
```



```
=====CMOS Models=====
.model NMOSC NMOS(
+ Level= 8 Tnom=27.0
-----Process-----
+ tox=160e-10 xj=0.25e-06 nch=0.5e+17
-----V threshold-----
+ vth0=0.72 nlx=0.12e-06
-----Bulk-----
+ k1=1.04 k2=-1.209E-01
+ cdsc=-2.4E-4 cdscd=-1.506E-04 cdscb=-2.219E-04
-----mobility-----
+ u0=678 ua=8.964e-10
+ ub=1.472e-18 uc=-4.441E-17 vsat=86000
-----Subthreshold-----
+ nfactor=1.8
+ cit=-5.0E-04 voff=-7.862E-02
+ eta0=4.441e-16 etab=-2.E-01 dsub=0.7
-----Hot electrons-----
* alpha0=1.61e-05 beta0=36.68
-----VAF-----
+ lint=.12e-06 pclm=.19 pscbe1=3.79e+08 pscbe2=9.4e-05
+ delta=0.01655 pvag=0.4484
-----Bulk diode-----
+ js=5.858e-08
-----Resistance-----
+ rsh=70 rdsw=375
+ wr=0.7586 prwb=0 prwg=-4.441E-17
-----Capacitance-----
+ cj=0.0002424 cjsw=2.73e-10 mj=0.3551 mjsw=0.3873
+ cgso=9e-13 cgdo=9e-13 cgbo=7e-10
+ pb=0.5614 pbsw=0.8 xpart=0
+ dlc=5e-08 dwc=1.5e-07
-----BulkChargeEffect-----
* a0=0.7 a1=0 a2=1 ags=0.05583
* b0=6.305e-08 b1=6.579e-08 keta=-1.531E-02
-----ShortChannel-----
+ dvt0=2.2 dvt1=0.53 dvt2=-1.521E-01 drout=0.76
+ pdiblcb=.4 pdiblc1=0.00886 pdiblc2=0.00029
-----NarrowChannel-----
+ w0=2.6e-04 wint=0.16e-06
+ ww=-9.525E-14 wwn=1.0
+ dvt0w=0 dvt1w=5.3e6 dvt2w=-1.E-01
+ k3=2.53 k3b=-5 dwg=0 dwb=0
-----Noise-----
* af=1 kf=1e-28 ef=0.95
-----Temperature-----
* pvsat=0 ute=-1.258E+00 kt1=-3.85E-01
* kt1l=0 kt2=-3.098E-02 ua1=5.705e-09
```

```

* ub1=-1.147E-17   uc1=-1.302E-01   at=20380
* prt=-3.287E+02   lk1=0           lk2=0
* lvsat=0          la0=0           lags=0           lute=0
+ luc=0
)

.model            PMOSC            PMOS(
+ Level= 8       Tnom=27.0
* -----Process-----
+ tox=1.725e-08  xj=2e-07           nch=1e+17
* -----V threshold-----
+ vth0=-0.90     nlx=1.84e-08
* -----Bulk-----
+ k1=0.3969      k2=0.03536
* -----mobility-----
+ u0=268         ua=4.124e-09
* ub=-3.8E-19    uc=-1.512E-02     vsat=140000
* -----Subthreshold-----
+ nfactor=.5016  voff=-0.08         nfactor=1.0016   vth0=-0.94
* cit=0.0001     etab=-1.057E-02   dsub=0.3501
* -----Hot electrons-----
+ alpha0=2.5e-08 beta0=28.92
* -----VAF-----
+ lint=.1e-06    pclm=3.2           pscbel=5e+08     pscbe2=1e-05
* delta=0.009    pvag=4
* -----Bulk diode-----
+ js=3.95e-08
* -----Resistance-----
+ rsh=135        rdsw=2500
* prwg=-7.2E-02 prwb=0.06          wr=0.8625
* -----Capacitance-----
+ cj=0.0002424  cjsw=2.73e-10     mj=0.3551        mjsw=0.3873
+ cgso=9e-13    cgdo=9e-13        cgbo=7e-10
* cdsc=-2.4E-4  cdscd=-1.506E-01 cdscb=-2.219E-04
* pb=0.85       pbsw=0.88         xpart=0
* dlc=5e-08     dwc=1.5e-07
* -----BulkChargeEffect-----
* a0=1          a1=0              a2=2              ags=0.268
* b0=5e-07      b1=1e-07          keta=-1.0E-02
* -----ShortChannel-----
* dvt0=2.9      dvt1=0.2          dvt2=-1.521E-01  drout=0.175
* pdiblc1=0     pdiblc1-          pdiblc2=0.001
* -----NarrowChannel-----
+ w0=2.6e-04    wint=0.16e-06
+ ww=-3.1E-19   wwn=1.9
* dvt0w=0.68    dvt1w=5.3e6       dvt2w=0.051
* k3=56         k3b=-3            dwg=0             dwb=1e-08
* -----Noise-----
+ af=0.8        kf=1.50e-30       ef=0.95
* -----Temperature-----
* ldelta=0.02282 lpdiblc1=0.01877  ute=-1.500E+00
* cgsl=1.5e-10   cgdl=1.5e-10      ckappa=0.2463     cf=0
* kt1=-4.684E-01 kt11=-2.0E-08     kt2=-2.818E-02
* ual=-2.E-10    ub1=-4.5E-18     uc1=-2.000E-02
+ at=-1.5E+05    prt=1400
)

```

.end

4.11.10 4.54PM  
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