**Inverter**

**Write the vhdl for the circuit. Here we consider the example of an inverter**

**inverter.vhd**

library IEEE; use IEEE.std\_logic\_1164.all;

entity inverter is port (input : in std\_logic; output : out std\_logic); end inverter;

architecture structural of inverter is begin output <= not (input); end structural;

**Run it through design vision and we can save a .v(verilog) file**

**inverter.v**

module inverter ( \input , \output ); input \input ; output \output ;

INV\_X1 U2 ( .A(\input ), .ZN(\output ) );

Endmodule

**Add the design(.v netlist) in encounter, Place and Route it and do RC Extraction where we get a .spef file.**

A typical SPEF file will have 4 main sections

– a header section,

– a name map section,

– a top level port section and

– the main parasitic description section.

Generally, SPEF keywords are preceded with a \*. For example, \*R\_UNIT, \*NAME\_MAP and \*D\_NET.

**inverter.spef**

\*SPEF "IEEE 1481-1998"

\*DESIGN "inverter"

\*DATE "Sat Mar 19 16:00:57 2011"

\*VENDOR "Silicon Perspective, A Cadence Company"

\*PROGRAM "Encounter"

\*VERSION "10.10-s002\_1"

\*DESIGN\_FLOW "PIN\_CAP NONE" "NAME\_SCOPE LOCAL"

\*DIVIDER /

\*DELIMITER :

\*BUS\_DELIMITER []

\*T\_UNIT 1 NS

\*C\_UNIT 1 PF

\*R\_UNIT 1 OHM

\*L\_UNIT 1 HENRY

\*Header Information

\*The header section is 14 lines containing information about

\* the design name,

\*the parasitic extraction tool,

\* naming styles

\* and units.

\*When reading SPEF, it is important to check the header for units as they vary across tools. By \*default, SPEF from Astro will be in pF and kOhm while SPEF from Star-RCXT will be in fF and \*Ohm.

\*Name Map Section

\*To reduce file size, SPEF allows long names to be mapped to shorter numbers preceded by a \*. \*This mapping is defined in the name \*map section.

\*NAME\_MAP

\*1 input

\*2 output

\*3 U2

\*Port Section

\*The port section is simply a list of the top level ports in a design. They are also annotated as \*input, output or bidirect with \*an I, O or B.

\*PORTS

\*1 I \*C 11 6

\*2 O \*C 11 6

\*Parasitics

\*Each extracted net will have a \*D\_NET section. This will usually consist of a \*D\_NET line, a \*CONN section, a \*CAP section, \*RES \*section and a \*END line. Single pin nets will not have a \*RES section. Nets connected by abutting pins will not have a \*CAP \*section.

\*The \*D\_NET line tells the net name and the net's total capacitance. This capacitance will be \*the sum of all the capacitances in the \*CAP section.

\*D\_NET \*1 0.000334148

\*The \*CONN section lists the pins connected to the net. A connection to a cell instance starts with a \*I. A connection to a top \*level port starts with a \*P.

\*The syntax of the \*CONN entries is:

\*I <pin name> <direction> \*C <xy coordinate> <loading or driving information>

\*Where:

\* The pin name is the name of the pin.

\* The direction will be I, O or B for input, output or bidirect.

\* The xy coordinate will be the location of the pin in the layout.

\* For an input, the loading information will be \*L and the pin's capacitance.

\* For an output, the driving information will be \*D and the driving cell's type.

\* Coordinates for \*P port entries may not be accurate because some extraction tools look for the physical location of the logical \*port (which does not exist) rather then the location of the corresponding pin.

\*CONN

\*P \*1 I \*C 11 6 \*L 0

\*I \*3:A I \*C 7 6 \*L 0 \*D INV\_X1

\*\*CAP Section

\*The \*CAP section provides detailed capacitance information for the net. Entries in the \*CAP section come in two forms, one for a \*capacitor lumped to ground and one for a coupled capacitor.

\*A capacitor lumped to ground has three fields,

\* an identifying integer,

\* a node name and

\* the capacitance value of this node

\* e.g

\*o1 regcontrol\_top/GRC/U9743:E 0.936057

\*A coupling capacitor has four fields,

\* an identifying integer,

\* two node names and

\* The values of the coupling capacitor between these two nodes

\* E.g

\*o2 regcontrol\_top/GRC/U9409:A regcontrol\_top/GRC/U10716:Z 0.622675

\*If netA is coupled to netB, the coupling capacitor will be listed in each net's \*CAP section.

\*CAP

1 \*1 0.000167074

2 \*1:1 0.000167074

\*\*RES Section

\*The \*RES section provides the resistance network for the net.

\*Entries in \*RES section contain 4 fields,

\* an identifying integer,

\* two node names and

\* the resistance between these two nodes.

\* E.g

\*o1 regcontrol\_top/GRC/U9743:E regcontrol\_top/GRC/U9407:Z 10.7916

\*The resistance network for a net can be very complex. SPEF can contain resistor loops or \*seemingly ridiculously huge resistors even if the layout is a simple point to point route. This is \*due how the extraction tool cuts nets into tiny pieces for extraction and then mathematically \*stitches them back together when writing SPEF.

\*RES

1 \*1:2 \*3:A 6

2 \*1:1 \*1:2 5

3 \*1 \*1:1 14.5804

\*END

\*D\_NET \*2 0.000331591

\*CONN

\*I \*3:ZN O \*C 7 5 \*L 0 \*D INV\_X1

\*P \*2 O \*C 11 6 \*L 0

\*CAP

1 \*3:ZN 8.42534e-05

2 \*2:1 8.42534e-05

3 \*2:3 8.15419e-05

4 \*2 8.15419e-05

\*RES

1 \*2:3 \*2 7.11607

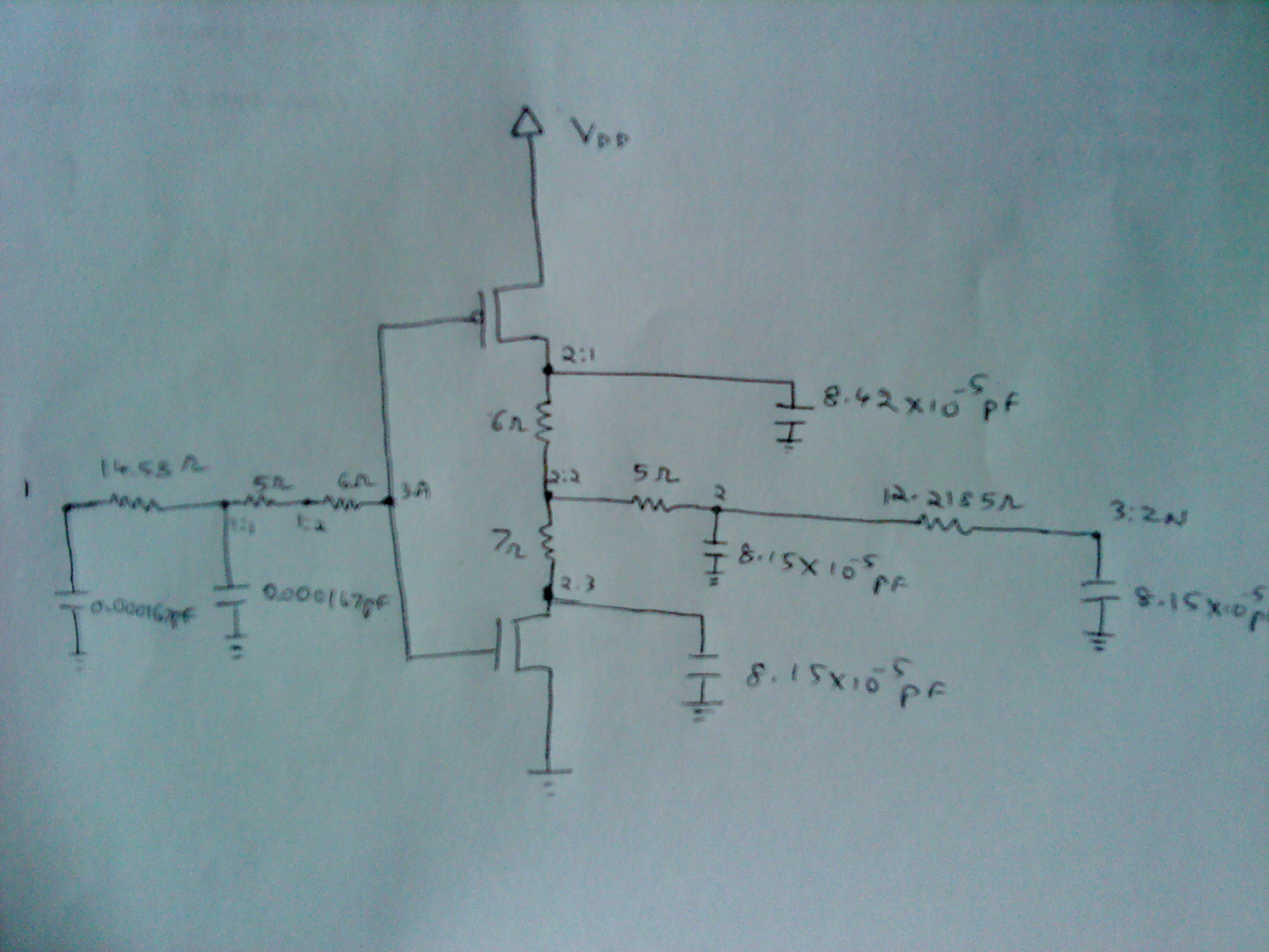
2 \*2:2 \*2:3 5

3 \*2:1 \*2:2 6

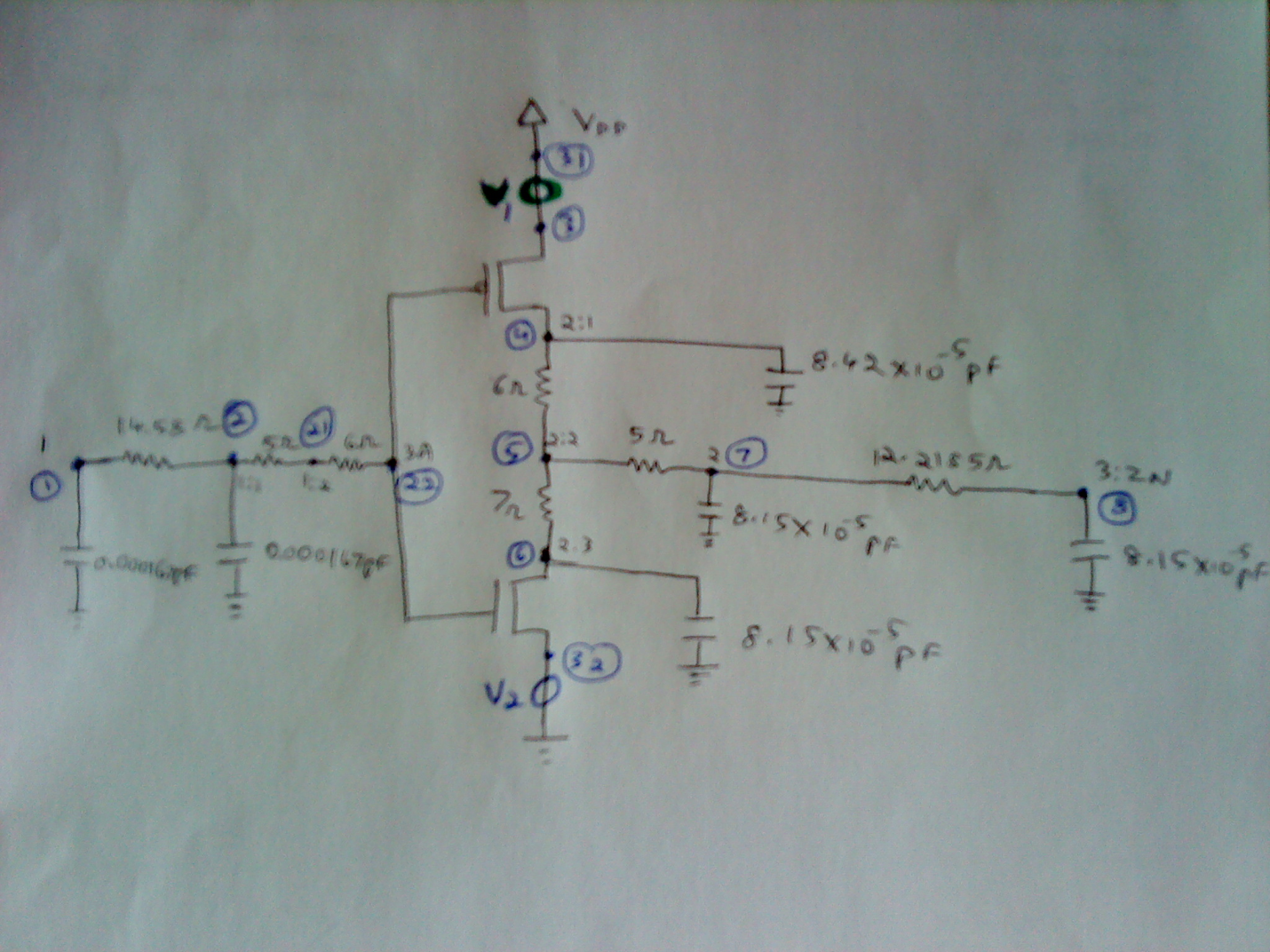
4 \*3:ZN \*2:1 12.2185

\*END

**Using the parasitic capacitance and resistance from the above .spef file the inverter circuit can be drawn as follows**



**With this as the basis, rename the nodes with simple numbers, write a design in hspice- .sp file**



inverter netlist  
vdd 31 0 dc 5v  
\*DC\_value   PEAK\_value  delay    risetime   falltime   pulse\_width   period  
Vin 1 0 pulse(5 1m 0 1n 1n 50u 100u)  
v1 31 3 dc 0v  
v2 32 0 dc 0v  
r1  1 2 14.58  
c1  1 0 0.000161pF  
c2  2 0 0.000161pF  
r4  5 7 5  
r11 2 21 5  
r12 21 22 6  
  
c5  7 0 0.0000815pF  
r5  7 8 12.2185  
c6  8 0 0.0000815pF  
XINV 22 5 3 32 INVERT  
\*  
.MODEL CMOSN NMOS (    
+VERSION = 3.1           LEVEL=49         TNOM    = 27             TOX     = 3.1E-9  
+XJ      = 1E-7           NCH     = 2.3549E17      VTH0    = 0.0485675  
+K1      = 0.3634695      K2      = -0.0277136     K3      = 1E-3  
+K3B     = 3.9409342      W0      = 1E-7           NLX     = 8.900764E-7  
+DVT0W   = 0              DVT1W   = 0              DVT2W   = 0  
+DVT0    = 1.2979753      DVT1    = 0.1605369      DVT2    = 0.2509178  
+U0      = 436.2279588    UA      = -3.51975E-10   UB      = 3.216114E-18  
+UC      = 4.919099E-10   VSAT    = 1.930256E5     A0      = 1.9922632  
+AGS     = 0.7096599      B0      = 1.892162E-6    B1      = 5E-6  
+KETA    = 0.05           A1      = 7.799989E-4    A2      = 0.3  
+RDSW    = 150            PRWG    = 0.3506787      PRWB    = 0.1097886  
+WR      = 1              WINT    = 7.71429E-9     LINT    = 1.039368E-8  
+DWG     = 1.205322E-8    DWB     = 8.815731E-9    VOFF    = -0.0331648  
+NFACTOR = 2.5            CIT     = 0              CDSC    = 2.4E-4  
+CDSCD   = 0              CDSCB   = 0              ETA0    = 2.754257E-6  
+ETAB    = -0.0108095     DSUB    = 4.0643E-6      PCLM    = 1.9769478  
+PDIBLC1 = 0.9710894      PDIBLC2 = 0.01           PDIBLCB = 0.1  
+DROUT   = 0.9993653      PSCBE1  = 7.973288E10    PSCBE2  = 5.02618E-10  
+PVAG    = 0.536394       DELTA   = 0.01           RSH     = 6.7  
+MOBMOD  = 1              PRT     = 0              UTE     = -1.5  
+KT1     = -0.11          KT1L    = 0              KT2     = 0.022  
+UA1     = 4.31E-9        UB1     = -7.61E-18      UC1     = -5.6E-11  
+AT      = 3.3E4          WL      = 0              WLN     = 1  
+WW      = 0              WWN     = 1              WWL     = 0  
+LL      = 0              LLN     = 1              LW      = 0  
+LWN     = 1              LWL     = 0              CAPMOD  = 2  
+XPART   = 0.5            CGDO    = 3.74E-10       CGSO    = 3.74E-10  
+CGBO    = 1E-12          CJ      = 9.581316E-4    PB      = 0.9759771  
+MJ      = 0.404514       CJSW    = 1E-10          PBSW    = 0.8002028  
+MJSW    = 0.6            CJSWG   = 3.3E-10        PBSWG   = 0.8002028  
+MJSWG   = 0.6            CF      = 0              PVTH0   = 2.009264E-4  
+PRDSW   = 0              PK2     = 1.30501E-3     WKETA   = 7.565815E-3  
+LKETA   = 0.0327047      PU0     = 4.4729531      PUA     = 1.66833E-11  
+PUB     = 0              PVSAT   = 653.2294237    PETA0   = 1E-4  
+PKETA   = -0.0101124      )  
.MODEL CMOSP PMOS (                               
+VERSION = 3.1            LEVEL=49        TNOM    = 27             TOX     = 3.1E-9  
+XJ      = 1E-7           NCH     = 4.1589E17      VTH0    = -0.2156906  
+K1      = 0.2680989      K2      = 4.539197E-3    K3      = 0.097375  
+K3B     = 6.5043674      W0      = 1E-6           NLX     = 2.836757E-7  
+DVT0W   = 0              DVT1W   = 0              DVT2W   = 0  
+DVT0    = 0              DVT1    = 1              DVT2    = 0.1  
+U0      = 106.670318     UA      = 1.152986E-9    UB      = 2.377339E-21  
+UC      = -1.93766E-11   VSAT    = 1.190739E5     A0      = 1.7356069  
+AGS     = 0.6166218      B0      = 7.467707E-6    B1      = 4.992767E-6  
+KETA    = 0.0157125      A1      = 8.723417E-3    A2      = 0.8713799  
+RDSW    = 105            PRWG    = -0.5           PRWB    = 0.5  
+WR      = 1              WINT    = 0              LINT    = 1.495916E-8  
+DWG     = 6.058254E-9    DWB     = -1.83713E-8    VOFF    = -0.1022829  
+NFACTOR = 1.5332272      CIT     = 0              CDSC    = 2.4E-4  
+CDSCD   = 0              CDSCB   = 0              ETA0    = 0.0110506  
+ETAB    = -2.941775E-3   DSUB    = 2.419246E-3    PCLM    = 0.2085802  
+PDIBLC1 = 9.972716E-4    PDIBLC2 = -1.39497E-13   PDIBLCB = -1E-3  
+DROUT   = 0.6860806      PSCBE1  = 1.849353E9     PSCBE2  = 5.675435E-10  
+PVAG    = 0.0149584      DELTA   = 0.01           RSH     = 6.6  
+MOBMOD  = 1              PRT     = 0              UTE     = -1.5  
+KT1     = -0.11          KT1L    = 0              KT2     = 0.022  
+UA1     = 4.31E-9        UB1     = -7.61E-18      UC1     = -5.6E-11  
+AT      = 3.3E4          WL      = 0              WLN     = 1  
+WW      = 0              WWN     = 1              WWL     = 0  
+LL      = 0              LLN     = 1              LW      = 0  
+LWN     = 1              LWL     = 0              CAPMOD  = 2  
+XPART   = 0.5            CGDO    = 3.42E-10       CGSO    = 3.42E-10  
+CGBO    = 1E-12          CJ      = 1.15643E-3     PB      = 0.8  
+MJ      = 0.4399866      CJSW    = 1.133806E-10   PBSW    = 0.8  
+MJSW    = 0.1146401      CJSWG   = 4.22E-10       PBSWG   = 0.8  
+MJSWG   = 0.1146401      CF      = 0              PVTH0   = 1.282832E-3  
+PRDSW   = 44.1361752     PK2     = 2.459655E-3    WKETA   = 0.0352131  
+LKETA   = 0.0128331      PU0     = -1.2608844     PUA     = -4.27994E-11  
+PUB     = 1.628153E-28   PVSAT   = -50            PETA0   = 7.039749E-5  
+PKETA   = -5.052402E-3    )  
.SUBCKT INVERT 1 2 3 32  
 mp1 4 1 3 3 cmosp W=0.480000U l=0.13u  
+AS=0.0384p AD=0.0384P PD=1.12U PS=1.12U  
mn1 6 1 32 0 cmosn W=0.16U L=0.13U  
+AS=0.0128P AD=0.0128P PD=0.48U PS=0.48U  
r2  4 2 6  
r3  2 6 7  
c3  4 0 0.0000842pF  
c4  6 0 0.0000815pF  
.ENDS  
.OP  
.tran .1u 200u 0  
\*switching energy pmos  
.meas tran switch\_qp integ I(v1) from=121ns to=240ns  
.meas tran switch\_energyp param='5\*switch\_qp'

\*switching energy  nmos  
.meas tran switch\_qn integ I(v2) from=121ns to=240ns  
.meas tran switch\_energyn param='5\*switch\_qn'  
\*avg leakage current  
.meas tran leak\_I avg I(v1) from=1ns to=600ns  
\*leakage energy  
.meas tran leak\_q integ I(v1) from=121ns to=240ns  
.meas tran leakage\_energy param='5\*leak\_q'  
\*leakage power  
.meas tran leak\_power param='5\*leak\_I'  
.print v1  
.PROBE   
.END

**To run hspice, type hpice on the terminal and give the path of the .sp file.**

**Leakge power and Switching power measured in the critical path will be shown in the .mto file generated after running hpice, shown below:**

$DATA1 SOURCE='HSPICE' VERSION='D-2010.03 32-BIT'  
.TITLE 'inverter netlist'  
 switch\_qp        switch\_energyp   switch\_qn        switch\_energyn      
 leak\_i           leak\_q           leakage\_energy   leak\_power          
 temper           alter#              
  4.198e-15        2.099e-14        5.038e-17        2.519e-16          
 -9.005e-09        4.198e-15        2.099e-14       -4.502e-08          
   25.0000           1.0000         