FOUNDED IN 2002

ANALOG POWER

10+ YEARS OF GROWTH

Use of Spice to Calculate Switching Losses

Concept

Trying to calculate switching losses in excel has many downsides

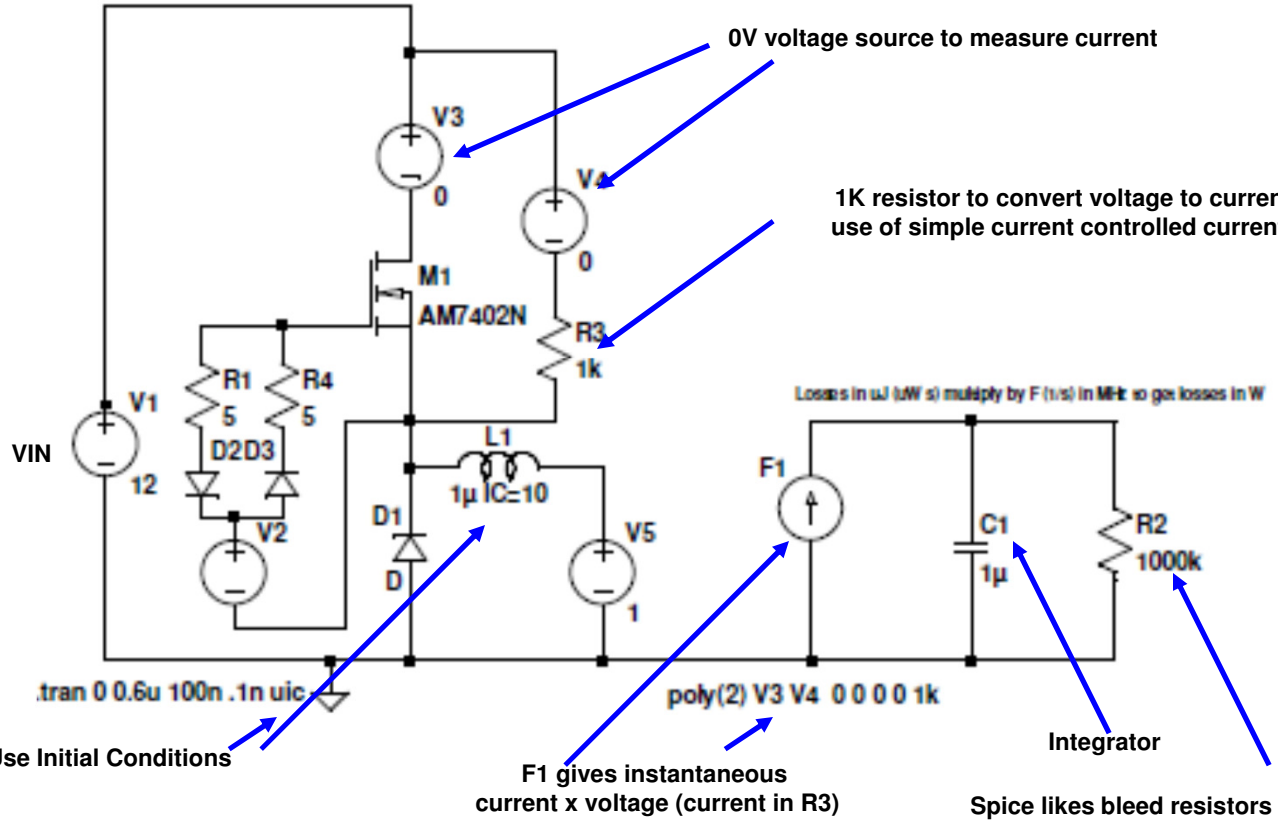
- Many parameters to enter, not given by vendor in flat file
- Complex equations are only a rough approximation
  - Capacitance changes with voltage
  - Losses (power) are not perfect shapes to calculate area from
  - Dead end in terms of improving and expanding the method
  - Pre-plateau losses require complex calculation using GFS/CISS and VGS(off) some of which are not provided
- Dead end in terms of improving and expanding the method
  - Not possible to expand to include other losses
- Model soon becomes impossible to debug or understand

Solution: Use Spice

Advantages of Spice

- Spice allows calculation of losses from modeled voltage and current
- Spice allows simple accurate analog integration (a capacitor)
- Spice allows cut and paste data entry from manufacturers' spice model
- Allows simple inclusion of driver rise time
- Easy to conceptualize
  - Check all waveforms eg VGS to see how it is behaving
  - Key parameters displayed on schematic
  - Easy to see why E.G. higher VGS causes lower losses
- Excellent free software versions available, or export Netlist to any Spice
  - E.G. LT Spice and NG Spice
- Fast (~<1s on average PC)
- Expandable – add other losses and or include thermal model, use for resonant circuits
- Allows for simple sizing of MOSFET – set RDS losses = ~switching losses

Implementation in LT Spice



Netlist

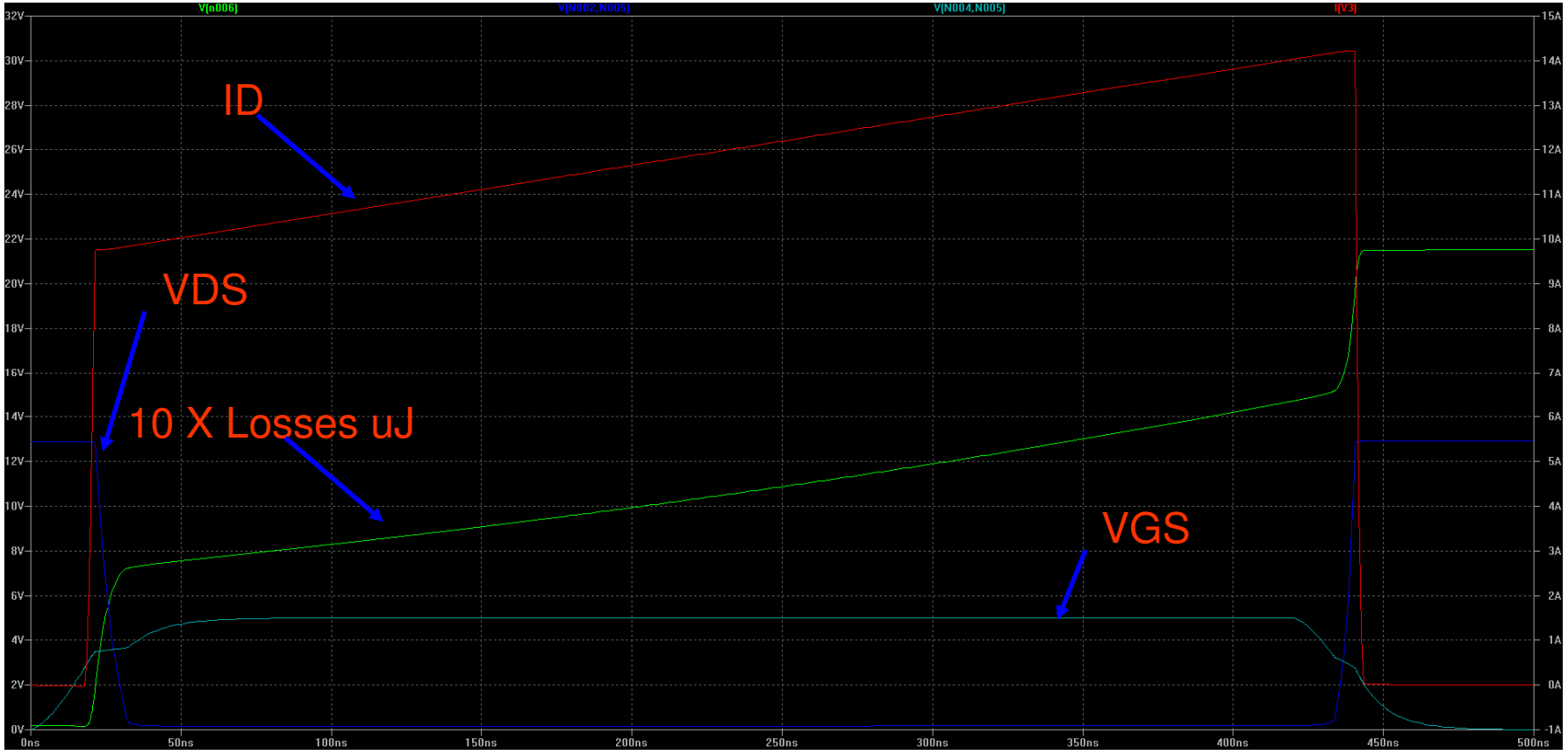
```
* C:\Program Files\LTC\LTspiceIV\switching_losses2a.asc
XM1 N002 N004 N005 AM7402N AM7402N  *model is AM7402N
L1 N005 N009 1µ IC=10  * note initial condition to set IL min
V1 N001 0 12  * Vin
V2 N010 N005 PULSE(0 5 100n 20n 20n .4u 4u 1)  *Driver. Note rise time of driver is included
R1 N004 N007 5 * Pull up driver resistance
D1 0 N005 D   * simple diode model used here, diode model can be complex for better results
F1 0 N006 poly(2) V3 V4 0 0 0 0 1k  * current is 1K x current in V3 x current in V4
R2 N006 0 1000k  *bleed resistor to help avoid iterations in spice
V3 N001 N002 0  *Voltage source for current sensing
R3 N003 N005 1k    * convert VDS into a current 1K gives only small errors
V4 N001 N003 0  *Voltage source for current sensing
C1 N006 0 1µ   *integrator capacitor
V5 N009 0 1    *perfect load
R4 N004 N008 5  * Pull down driver resistance
D2 N007 N010 D_I  *perfect diode
D3 N010 N008 D_I  *perfect diode
```

Spice MOSFET Model

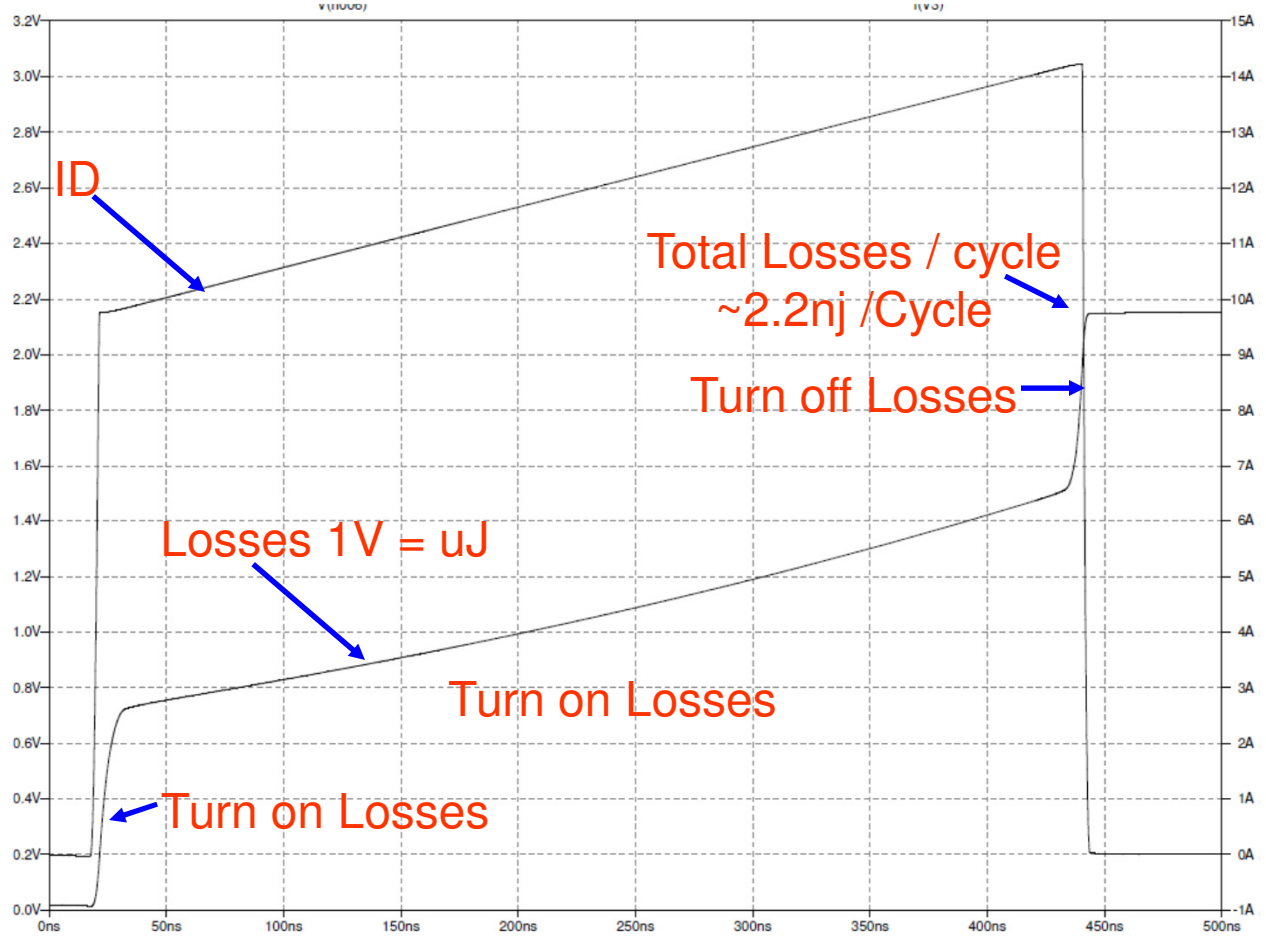
- Level 3 model allows good modeling of switching losses and RDS at 25C
- CRSS varies with VDS
- RG, L_{Source} included
- FAST

```
.SUBCKT AM7402N 1 2 3
*Nom Temp=25 deg C
Mos1 4 5 6 6 APLMOS w=1 l=0.25u
.MODEL APLMOS NMOS (LEVEL = 3  vto=2.4
      NSUB=2e+17 KP = 15u kappa=0.12
      CGDO=30p CGSO=1366p)
Rdrain 1 4  5.5m
Dbody 6 1 BodyD
.MODEL BodyD D (IS=0.8e-12 RS=8e-3
      CJO=250p M=0.54)
Lsource 3 6 0.3e-9
Rsource 3 6 0.002
Rgate 2 5 1
Dcgd 5 7 Crss
.MODEL Crss D (RS=1e-3 CJO=270p M=0.44)
B1 7 1 V= (abs(v(5)-V(1))+(v(5)-V(1)))/2
B2 1  8  V= (abs(v(1)-V(5))+(v(1)-V(5)))/2
C2 8 5 325p IC=0
R2 8 5 1e9
.ENDS
```

Output


V(n006)
V(N002,N005)
V(N004,N005)
I(V3)
ID
VDS
10 X Losses uJ
VGS
32V
30V
28V
26V
24V
22V
20V
18V
16V
14V
12V
10V
8V
6V
4V
2V
0V
15A
14A
13A
12A
11A
10A
9A
8A
7A
6A
5A
4A
3A
2A
1A
0A
-1A
0ns
50ns
100ns
150ns
200ns
250ns
300ns
350ns
400ns
450ns
500ns

Losses


ID
Total Losses / cycle
~2.2nj /Cycle
Turn off Losses
Losses 1V = uJ
Turn on Losses
Turn on Losses
3.2V
3.0V
2.8V
2.6V
2.4V
2.2V
2.0V
1.8V
1.6V
1.4V
1.2V
1.0V
0.8V
0.6V
0.4V
0.2V
0.0V
15A
14A
13A
12A
11A
10A
9A
8A
7A
6A
5A
4A
3A
2A
1A
0A
-1A
0ns
50ns
100ns
150ns
200ns
250ns
300ns
350ns
400ns
450ns
500ns

Summary

- Spice allows much more accurate modeling of switching losses
  - Excel models are too simple to be of any use
- Spice allows simple calculation of turn on, turn off and conduction losses
- MOSFET vendors provide spice models in ascii form that are more detailed than data sheet parameters
- Method can be extended to bottom fet
- Thermal models can be added