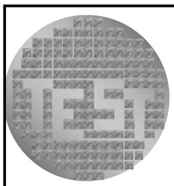
VLSI Design



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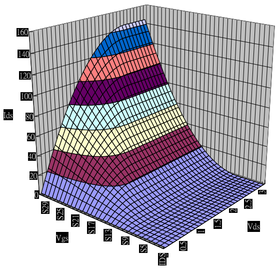
Basic Model of a MOSFET

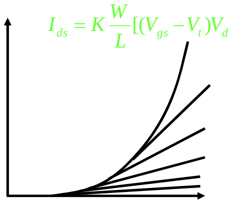


Saturation region:

$$I_{ds} = K\frac{W}{L}\cdot\frac{(V_{gs}-V_t)^2}{2}$$

Linear region:

$$I_{ds} = K\frac{W}{L}[(V_{gs}-V_t)V_{ds}-\frac{V_{ds}^2}{2}]$$

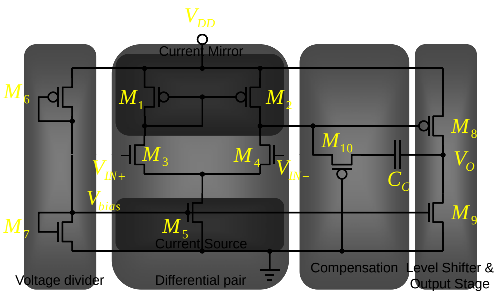


For recent micron tech:

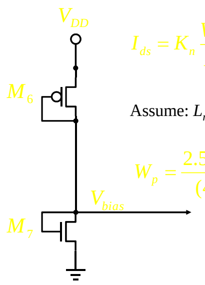
$$K_n \approx 2.5K_p \approx 100\mu A$$

$$V_t \approx 0.5V$$

A 10T+C 2-Stage Simple OP AMP



Voltage-Divider Biasing Circuit



$$I_{ds} = K_n\frac{W_n}{L_n}\cdot\frac{(V_{bias}-V_{tn})^2}{2} = K_p\frac{W_p}{L_p}\cdot\frac{(V_{DD}-V_{bias}-|V_{tp}|)^2}{2}$$

Assume: L_n=L_p, K_n=2.5K_p, V_{tn}=|V_{tp}|=0.5V, V_{DD}=5V,

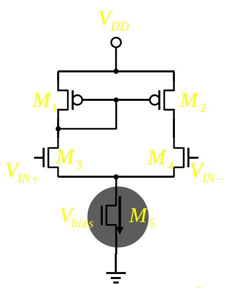
$$W_p = \frac{2.5(V_{bias}-0.5)}{(4.5-V_{bias})}W_n$$

Differential Amplifier (Simple OTA)

$$r_L = \frac{L_1}{KW_1(v_{gs1}-V_t)}$$

$$A_v = -g_m r_L$$

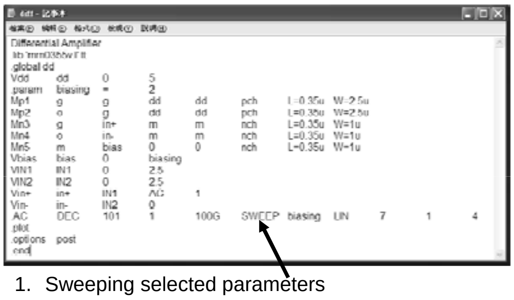
$$g_{m3} = K_n\frac{W_3}{L_3}(v_{gs3}-V_t)$$



$$I = K_n\frac{W_5}{L_5}\cdot\frac{(V_{bias}-V_{tn})^2}{2}$$

Typical design constraints
if all L are the same and |V_{GS}| are similar:

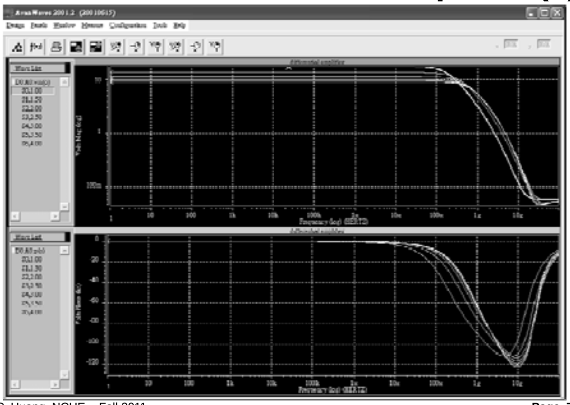
Simulation – Differential Amplifier (1)



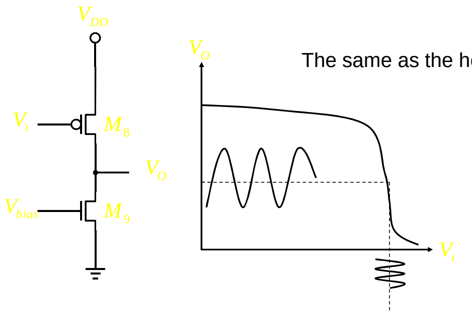
```
Differential Amplifier
.lib 'mm0355w.l' tt
.global dd
Vdd     dd      0       5
.param  biasing =       2
Mp1     g       g       dd      dd      pch     L=0.35u W=2.5u
Mp2     o       g       dd      dd      pch     L=0.35u W=2.5u
Mn3     g       in+     m       m       nch     L=0.35u W=1u
Mn4     o       in-     m       m       nch     L=0.35u W=1u
Mn5     m       bias    0       0       nch     L=0.35u W=1u
Vbias   bias    0       biasing
VIN1    IN1     0       2.5
VIN2    IN2     0       2.5
Vin+    in+     IN1     AC      1
Vin-    in-     IN2     0
.AC     DEC     101     1       100G    SWEEP   biasing LIN     7       1       4
.plot
.options        post
.end
```

1. Sweeping selected parameters
2. Optimization
3. Alter
4. C Srcript

Simulation – Differential Amplifier (2)



Level Shifter & Driver



The same as the homework 1.

Operating Points

Add **.OP** operating-point analysis

```
Differential Amplifier
.lib 'mm0355v.l' tt
.global dd
Vdd     dd      0       5
Mp1     g       g       dd      dd      pch     L=0.35u  W=2.5u
Mp2     o       g       dd      dd      pch     L=0.35u  W=2.5u
Mn3     g       in+     m       m       nch     L=0.35u  W=1u
Mn4     o       in-     m       m       nch     L=0.35u  W=1u
Mn5     m       bias    0       0       nch     L=0.35u  W=1u
Mp6     bias    bias    dd      dd      pch     L=0.35u  W=1u
Mn7     bias    bias    0       0       nch     L=0.35u  W=2.5u

VIN1    IN1     0       2.5
VIN2    IN2     0       2.5
Vin+    in+     IN1     AC      1
Vin-    in-     IN2     0
.AC     DEC     101     1       10G
.options post
.OP
.end
```

```
***** operating point status is all        simulation time is     0.
   node      =voltage      node      =voltage      node      =voltage

 +0:bias    =   1.3476  0:dd       =   5.0000  0:g        =   3.6991
 +0:in+     =   2.5000  0:in-      =   2.5000  0:in1      =   2.5000
 +0:in2     =   2.5000  0:m        =   1.4520  0:o        =   3.6991
```

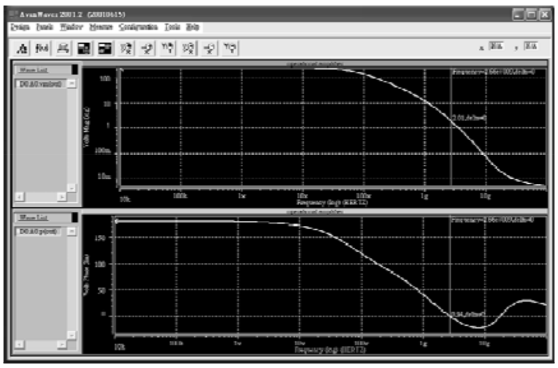

Example

A 9T Non-Compensated OPAMP Design

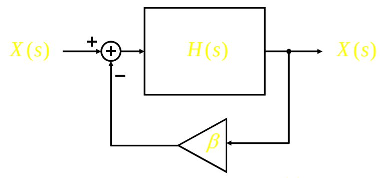
```
Operational Amplifier
.lib 'mm0355v.l' tt
.global dd
Vdd     dd      0       5
Mp1     g       g       dd      dd      pch     L=0.35u W=2.5u
Mp2     o       g       dd      dd      pch     L=0.35u W=2.5u
Mn3     g       in+     m       m       nch     L=0.35u W=1u
Mn4     o       in-     m       m       nch     L=0.35u W=1u
Mn5     m       bias    0       0       nch     L=0.35u W=1u
Mp6     bias    bias    dd      dd      pch     L=0.35u W=1u
Mn7     bias    bias    0       0       nch     L=0.35u W=2.5u
Mp8     out     o       dd      dd      pch     L=0.35u W=4u
Mn9     out     bias    0       0       nch     L=0.35u W=1u

VIN1    IN1     0       2.5
VIN2    IN2     0       2.5
Vin+    in+     IN1     AC      1
Vin-    in-     IN2     0
.AC     DEC     101     1       100G
.options        post
.end
```


Example

A 9T OPAMP Design



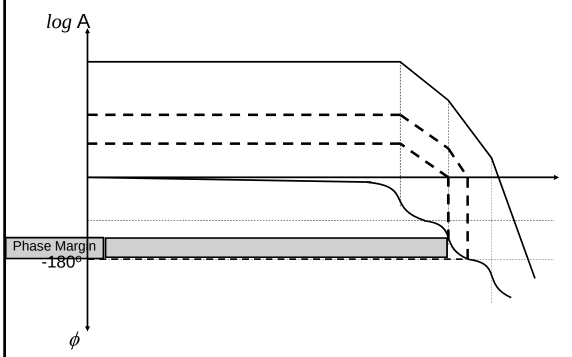
Basic Negative Feedback System



Close loop transfer function: $T(s)=\frac{H(s)}{1+\beta H(s)}$

Barkhausen's criteria: $|\beta H|\le 1 @ \angle\beta H=-180^\circ \Rightarrow$ Stable

Typical Compensation on Bode Plot

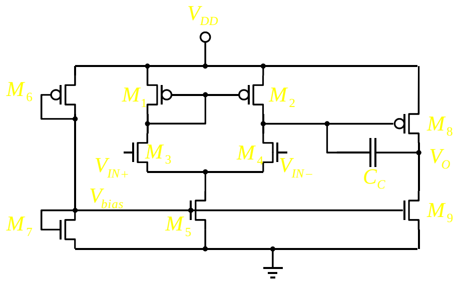


Typical Frequency Compensation

1. Dominant-Pole Compensation
2. Pole-Zero Compensation
3. Miller Compensation (Pole-Splitting)

Miller Compensation

A 9T+C OPAMP



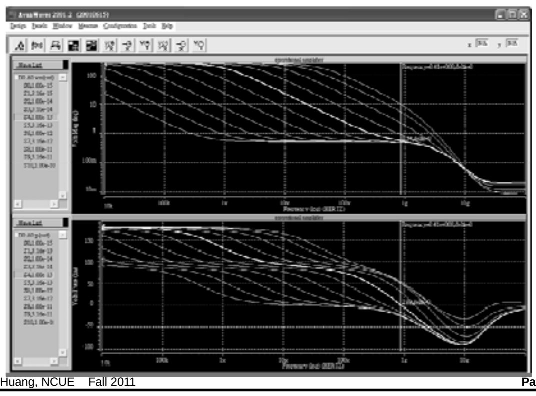
Miller Compensation

A 9T+C OPAMP

```
Operational Amplifier
.lib 'mm0355v.l' tt
.global dd
.param  Cap     =       0
Vdd     dd      0       5
Mp1     g       g       dd      dd      pch     L=0.35u W=2.5u
Mp2     o       g       dd      dd      pch     L=0.35u W=2.5u
Mn3     g       in+     m       m       nch     L=0.35u W=1u
Mn4     o       in-     m       m       nch     L=0.35u W=1u
Mn5     m       bias    0       0       nch     L=0.35u W=1u
Mp6     bias    bias    dd      dd      pch     L=0.35u W=1u
Mn7     bias    bias    0       0       nch     L=0.35u W=2.5u
Mp8     out     o       dd      dd      pch     L=0.35u W=4u
Mn9     out     bias    0       0       nch     L=0.35u W=1u
Cc      out     o       Cap

VIN1    IN1     0       2.5
VIN2    IN2     0       2.5
Vin+    in+     IN1     AC      1
Vin-    in-     IN2     0
.AC     DEC     101     10K     100G    SWEEP   Cap     DEC  2  1f  100p
.options        post
.end
```


Miller Compensation

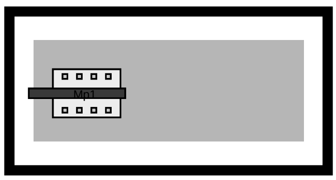
A 9T+C OPAMP



Cross-Match Floor-Planning (1)

Basic Matching:

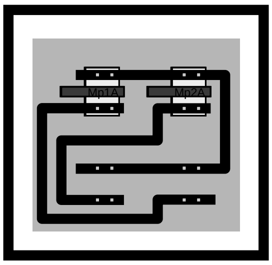
```
Mp1     g       g       dd      dd      pch     L=0.35u W=2.5u
Mp2     o       g       dd      dd      pch     L=0.35u W=2.5u
```



Cross-Match Floor-Planning (2)

Cross Matching:

```
Mp1   g   g   dd   dd   pch   L=0.35u  W=1.25u  M=2
Mp2   o   g   dd   dd   pch   L=0.35u  W=1.25u  M=2
```



Cross-Match Floor-Planning (3)

An Example for Coarse Floor-planning: