

Lab. 11

# **CHARACTERIZATION OF DIFFERENTIAL AMPLIFIER**

# 1. DC bias and input range

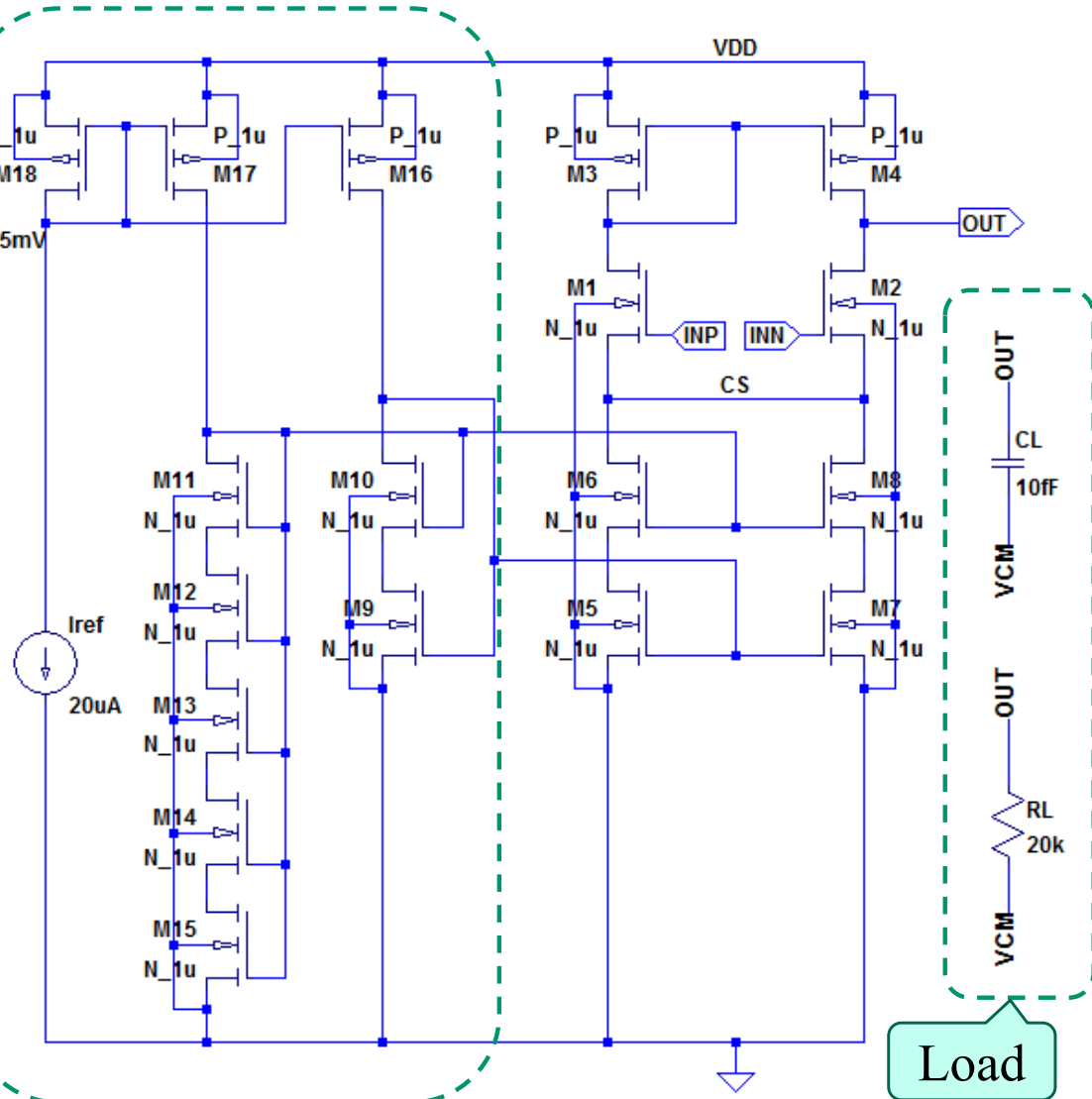
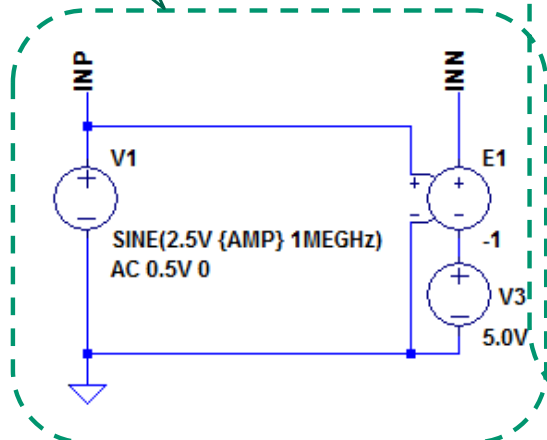
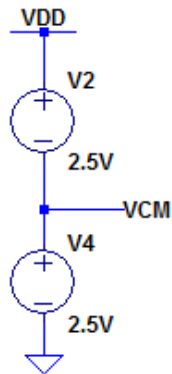
- Carry out the analysis of the differential amplifier shown in the next slide. In the DC analysis, use  $20\text{ k}\Omega$  load resistor ( $R_L$ ) to sink and source the output current.
- Check the output voltage, the input voltage, the drain current of M1 and M2, the common source voltage  $V(MC)$ .
  - Note: The input and output signal is biased by the common mode voltage  $V_{CM}$ . Then the load resistor must be connected to  $V_{CM}$  node.

# Schematic

Bias circuit

```
.lib cmos.lib
.dc V1 0V 5V 10mV
;ac dec 100 1Hz 10GHz
.tran 0 20us 10us 38.14697266ps
.options plotwinsize=0
.step param AMP list 0.025mV 0.25mV 2.5mV
```

Differential signal source



Load

# Parameters

MOSFET	L(m)	W(m)	M	AD, AS(m <sup>2</sup> )	PD, PS(m)	W/L
M1, M2	2u	20u	1	60p	26u	10
M3, M4	2u	20u	1	60p	26u	10
M5-M15	2u	10u	1	30p	16u	5
M16-M18	2u	10u	3	30p	16u	15

# Differential signal source

**Independent Voltage Source - V1**

Functions

- (none)
- PULSE(V1 V2 Tdelay Trise Tfall Ton Period Ncycles)
- SINE(Voffset Vamp Freq Td Theta Phi Ncycles)
- EXP(V1 V2 Td1 Tau1 Td2 Tau2)
- SFFM(Voff Vamp Fcar MDI Fsig)
- PWL(t1 v1 t2 v2...)
- PWL FILE:

DC offset[V]:   
Amplitude[V]:   
Freq[Hz]:   
Tdelay[s]:   
Theta[1/s]:   
Phi[deg]:   
Ncycles:

Make this information visible on schematic:

DC Value

DC value:

Make this information visible on schematic:

Small signal AC analysis(AC)

AC Amplitude:   
AC Phase:

Make this information visible on schematic:

Parasitic Properties

Series Resistance[Ω]:   
Parallel Capacitance[F]:

Make this information visible on schematic:

Substitute  
by .step  
directive

## 2. AC analysis

- Carry out the AC analysis of the differential amplifier shown in the previous page. In the AC and TRAN analysis, use the 10fF capacitive load.
- Measure the differential gain, the cut-off frequency, the unity gain frequency, and the phase margin.
  - Remove the load resistor  $R_L$  or set the  $R_L$  to  $1T\Omega$ , because the voltage gain is degraded by  $R_L$ .
  - Set the AC magnitude of the signal source = 0.5V, that is, the amplitude of the differential signal is given at 1.0V. In an AC analysis, the distortion cannot be considered, because the analysis is carried out for the linearized small-signal equivalent circuit. Therefore, the amplitude of signal source is usually set at 1.0V for convenience to obtain the sensitivity to the input amplitude.

# 3. TRAN analysis

- Carry out the TRAN analysis of the differential amplifier shown in the previous page.
  - The amplitude of the input signal is stepped by `.step param` directive.
- Show the output waveform and FFT results.
  - FFT requires the large number of point in the waveform. The automatic data deletion must be suppressed by the `.option` directive.
  - `.options plotwinsize=0`
  - FFT can be applied to the  $2^N$  data. Here the number of data is set to the default value ( $262144 = 2^{18}$ ). Please see the comment on the FFT setting in <http://jaco.ec.t.kanazawa-u.ac.jp/edu/ec2/ltspace/26.html>

# Parameter of transient analysis

The image shows two overlapping dialog boxes from a simulation software. The background box is the 'Edit Simulation Command' dialog, and the foreground box is the 'Select Waveforms to include in FFT' dialog. Two green callout boxes provide annotations: one pointing to the 'Stop Time' field in the first dialog, and another pointing to the 'Number of data point samples in time' field in the second dialog.

**10\*Period of signal**

**Stop time/262144**

**Edit Simulation Command**

Transient AC Analysis DC sweep Noise DC Transient DC op pnt

Perform a non-linear, time-domain simulation.

Stop Time: 20us

Time to Start Saving Data: 10us

Maximum Timestep: 38.14697266ps

Start external DC supply voltages at 0V:

Stop simulating if steady state is detected:

Don't reset T=0 when steady state is detected:

Step the load current source:

Skip Initial operating point solution:

Syntax: .tran <Tprint> <Tstop> [<Tstart> [<Tmaxstep>]] [<option> [<option>] ...]

.tran 0 20us 10us 38.14697266ps

Cancel OK

**Select Waveforms to include in FFT**

NOTE: Fourier components are normalized to correspond to the time domain RMS amplitude.

Ctrl-Click to toggle

V(cs)	V(n006)	I(V1)	Ib(M8)	Id(M1)	Id(M12)	Ig(M5)	Ig(M16)	Is(N
V(inn)	V(n007)	I(V2)	Ib(M9)	Id(M2)	Id(M13)	Ig(M6)	Ig(M17)	Is(N
V(inp)	V(n008)	I(V3)	Ib(M10)	Id(M3)	Id(M14)	Ig(M7)	Ig(M18)	Is(N
V(out)	V(n009)	I(V4)	Ib(M11)	Id(M4)	Id(M15)	Ig(M8)	Is(M1)	Is(N
V(vcm)	V(n010)	Ib(M1)	Ib(M12)	Id(M5)	Id(M16)	Ig(M9)	Is(M2)	Is(N
V(vdd)	V(n011)	Ib(M2)	Ib(M13)	Id(M6)	Id(M17)	Ig(M10)	Is(M3)	Is(N
V(n001)	V(n012)	Ib(M3)	Ib(M14)	Id(M7)	Id(M18)	Ig(M11)	Is(M4)	Is(N
V(n002)	I(C1)	Ib(M4)	Ib(M15)	Id(M8)	Ig(M1)	Ig(M12)	Is(M5)	Is(N
V(n003)	I(E1)	Ib(M5)	Ib(M16)	Id(M9)	Ig(M2)	Ig(M13)	Is(M6)	Is(N
V(n004)	I(Iref)	Ib(M6)	Ib(M17)	Id(M10)	Ig(M3)	Ig(M14)	Is(M7)	Is(N
V(n005)	I(R1)	Ib(M7)	Ib(M18)	Id(M11)	Ig(M4)	Ig(M15)	Is(M8)	Is(N

Number of data point samples in time: 262144

Quadratic interpolate uncompressed data

Use Extent of Simulation Data

Use current zoom Extent

Specify a time range

Binomial Smoothing done before FFT and windowing

Number of Points: 3

Windowing (Periodic and normalized to unit area)

Windowing Function: (none)

Kaiser-Bessel Parameter Beta: 2

Preview Window

NOTE: The DC component is removed before windowing.

Reset to Default Values