Project-2 [Current mirror]

A Project Submitted

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(Section-A)

Under the Supervision of

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In Partial Fulfilment of

the requirements for the course of

EE1124 (Analog Electronics)

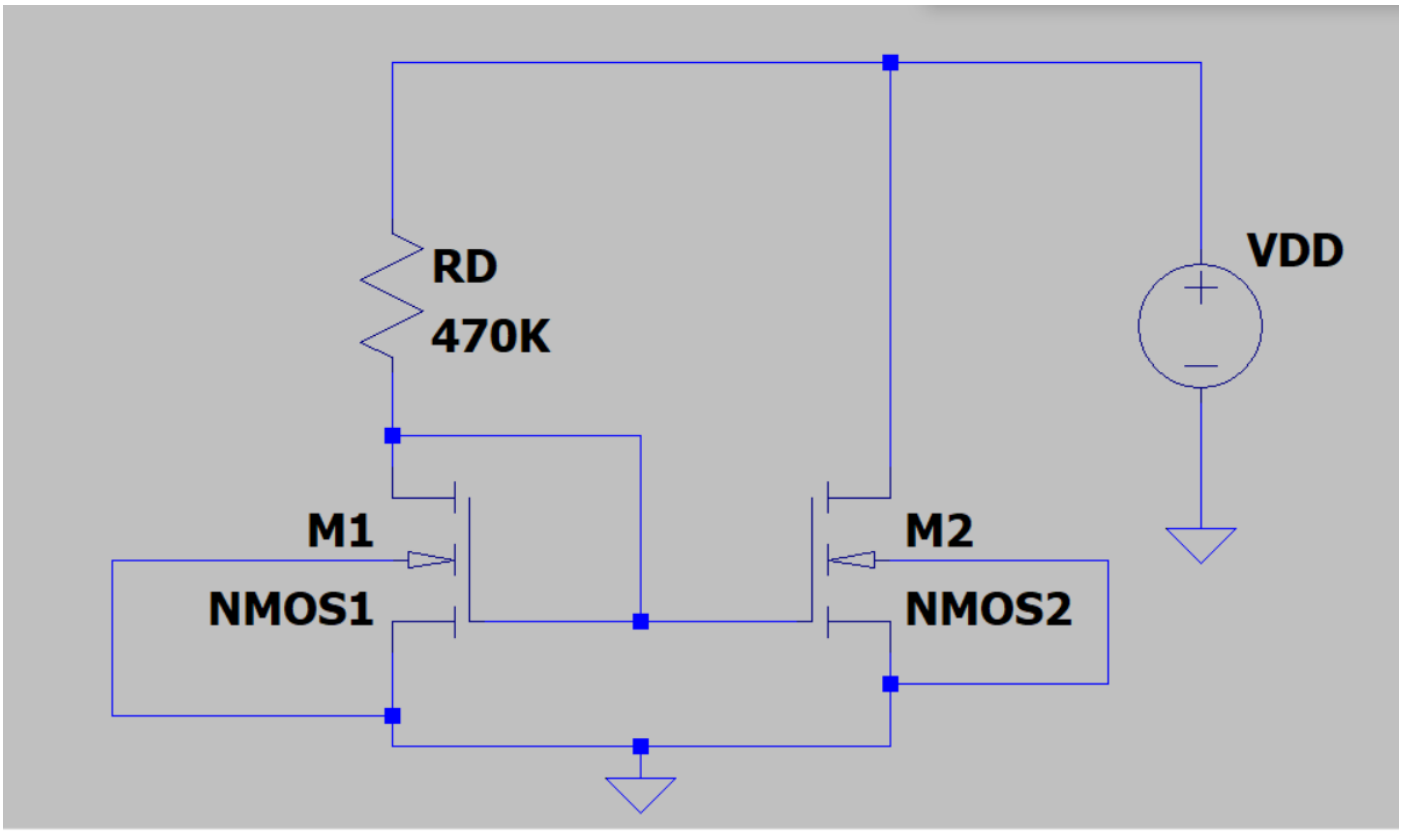
To the

Institute of Engineering And Technology (IET)

J.K Lakshmipat University Jaipur

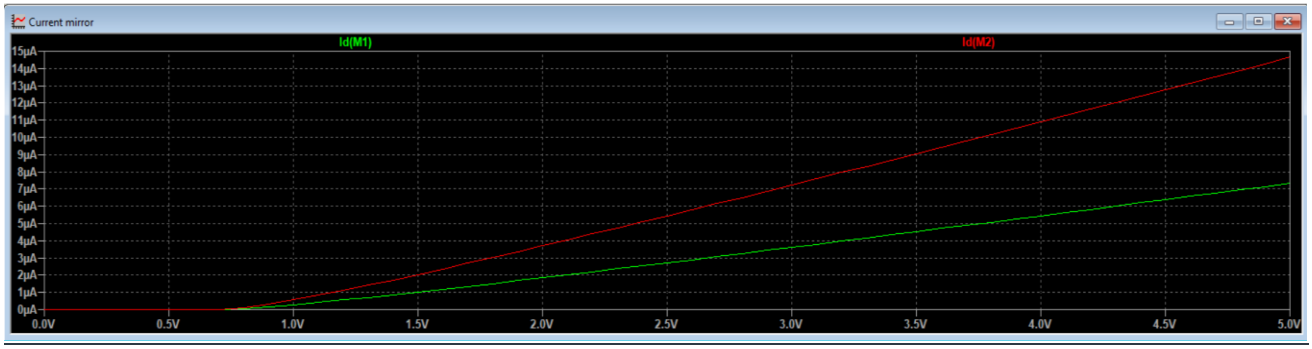
Aim: Dc and Transient Analysis of the Current Mirror and Cascoded Current Mirror and calculating the Iout/Iref and verifying it theortically.

Part A: Schematic



DC Analysis:

1. **When Lambda = 0**
   Simulation:




```
.dc VDD 0 5 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=20u L=5u lambda=0 kp=10u gamma=0)
```

Vdd	Iref	Iout	Iout/Iref (By Simulation)	Iout/Iref (By Calculation)
2V	1.85066uA	3.70132uA	2	2
3V	3.61146uA	7.22892uA	2	2
4V	5.45048uA	10.901uA	2	2

Observation Table-1

a. **When Vdd = 2V:**

From Simulation:

```
.meas iref FIND Id(M1) WHEN VDD=2V
.meas iout FIND Id(M2) WHEN VDD=2V
.meas ratio param iout/iref
```

```
iref: id(m1)=1.85066e-06 at 2
iout: id(m2)=3.70132e-06 at 2
ratio: iout/iref=2
```

From Calculation:

Iout/Iref = (W/L)2/(W/L)1 = (20/5)/(10/5) = 2

b. **When Vdd = 3V**

From Simulation:

```
.meas iref FIND Id(M1) WHEN VDD=3V
.meas iout FIND Id(M2) WHEN VDD=3V
.meas ratio param iout/iref
```

```
iref: id(m1)=3.61446e-06 at 3
iout: id(m2)=7.22892e-06 at 3
ratio: iout/iref=2
```

From Calculation:

Since, Iout/Iref depends on W and L also Lambda=0 therefore it's value remains same at every value of VDD.

c. **When Vdd = 4V**

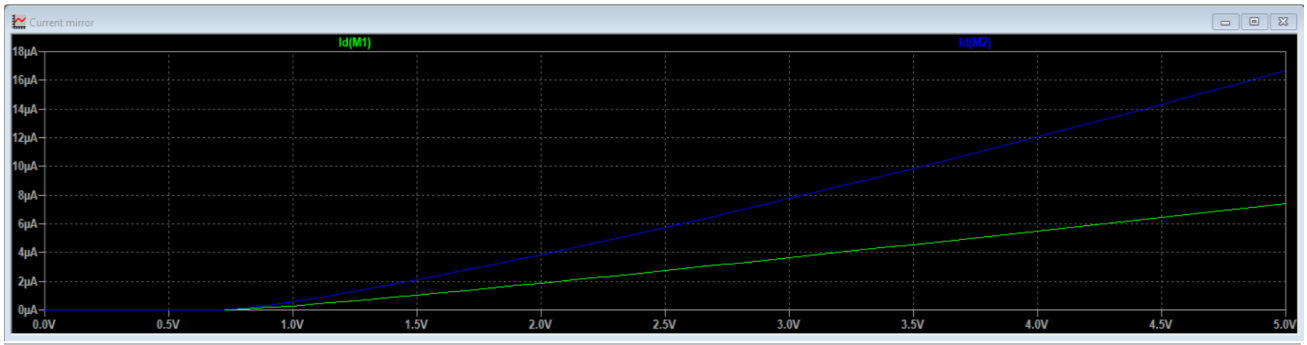
From Simulation:

```
.meas iref FIND Id(M1) WHEN VDD=4V
.meas iout FIND Id(M2) WHEN VDD=4V
.meas ratio param iout/iref
```

```
iref: id(m1)=5.45048e-06 at 4
iout: id(m2)=1.0901e-05 at 4
ratio: iout/iref=2
```

2. **When Lamda = 0.04**

Simulation:




```
.dc VDD 0 5 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0.04 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=20u L=5u lambda=0.04 kp=10u gamma=0)
```

Vdd	Iref	Iout	Iout/Iref (By Simulation)	Iout/Iref (By Calculation)
2V	1.86668uA	3.85874uA	2.06717	2.06738
3V	3.64154uA	7.75725uA	2.13021	2.13008
4V	5.48804uA	12.0476uA	2.19526	2.19530

Observation Table-2

a. **When Vdd = 2V**

From Simulation:

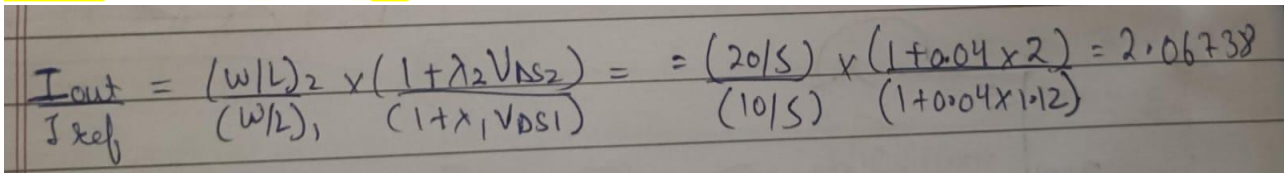
```
.meas iref FIND Id(M1) WHEN VDD=2V
.meas iout FIND Id(M2) WHEN VDD=2V
.meas ratio param iout/iref
```

```
iref: id(m1)=1.86668e-06 at 2
iout: id(m2)=3.85874e-06 at 2
ratio: iout/iref=2.06717
```

From Calculation:

By Setting the value of Vdd=2V and DC Operating Point we get the value of Vds2 and Vds1

Name:	m1	m2
Model:	nmos1	nmos2
Id:	1.87e-06	3.86e-06
Vgs:	1.12e+00	1.12e+00
Vds:	1.12e+00	2.00e+00



b. **When Vdd = 3V**

From Simulation:

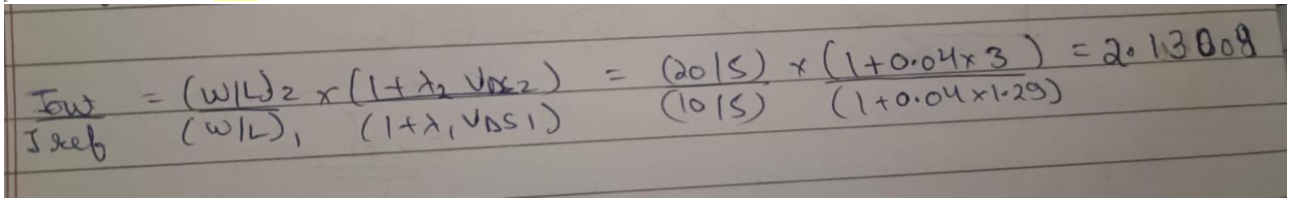
```
.meas iref FIND Id(M1) WHEN VDD=3V
.meas iout FIND Id(M2) WHEN VDD=3V
.meas ratio param iout/iref
```

```
iref: id(m1)=3.64154e-06 at 3
iout: id(m2)=7.75725e-06 at 3
ratio: iout/iref=2.13021
```

From Calculation:

By Setting the value of Vdd=3V and DC Operating Point we get the value of Vds2 and Vds1

Name:	m1	m2
Model:	nmos1	nmos2
Id:	3.64e-06	7.76e-06
Vgs:	1.29e+00	1.29e+00
Vds:	1.29e+00	3.00e+00



c. **When Vdd = 4V**

From Simulation:

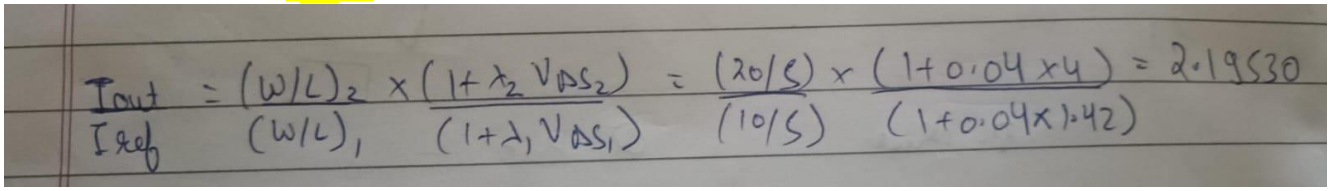
```
.meas iref FIND Id(M1) WHEN VDD=4V
.meas iout FIND Id(M2) WHEN VDD=4V
.meas ratio param iout/iref
```

```
iref: id(m1)=5.48804e-06 at 4
iout: id(m2)=1.20476e-05 at 4
ratio: iout/iref=2.19526
```

From Calculation:

By Setting the value of Vdd=4V and DC Operating Point we get the value of Vds2 and Vds1

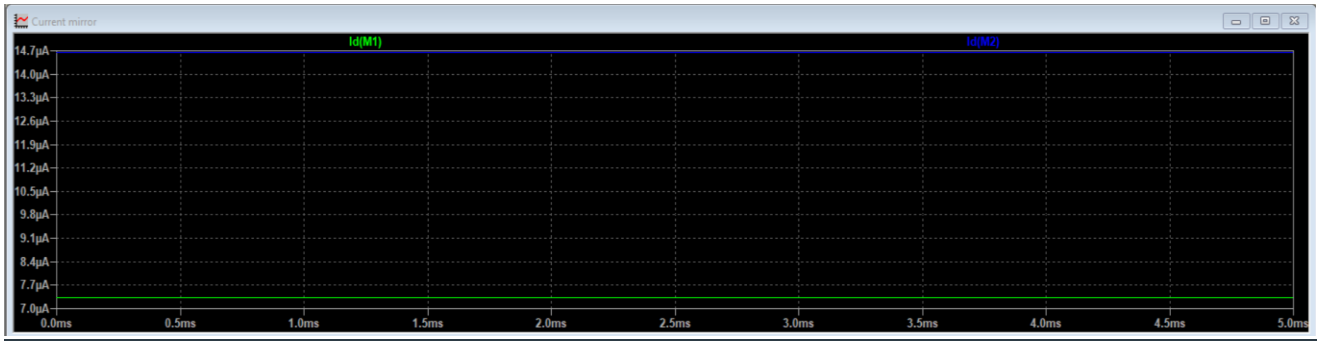
Name:	m1	m2
Model:	nmos1	nmos2
Id:	5.49e-06	1.20e-05
Vgs:	1.42e+00	1.42e+00
Vds:	1.42e+00	4.00e+00



Transient Analysis:

1. **When Lambda=0**

Simulation:




```
.tran 0 5ms 0 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=20u L=5u lambda=0 kp=10u gamma=0)
```

Time	Iref	Iout	Iout/Iref By Simulation	Iout/Iref By Calculation
2ms	7.32763uA	14.6553uA	2	2
4ms	7.32763uA	14.6553uA	2	2

Observation Table-3

a. **When Time=2ms**

By Simulation:

```
.meas iref FIND Id(M1) WHEN time=2ms
.meas iout FIND Id(M2) WHEN time=2ms
.meas ratio param iout/iref
```

```
iref: id(m1)=7.32763e-06 at 0.002
iout: id(m2)=1.46553e-05 at 0.002
ratio: iout/iref=2
```

By Calculation:

Iout/Iref = (W/L)2/(W/L)1 = (20/5)/(10/5) = 2

b. **When Time=4ms**

By Simulation:

```
.meas iref FIND Id(M1) WHEN time=4ms
.meas iout FIND Id(M2) WHEN time=4ms
.meas ratio param iout/iref
```

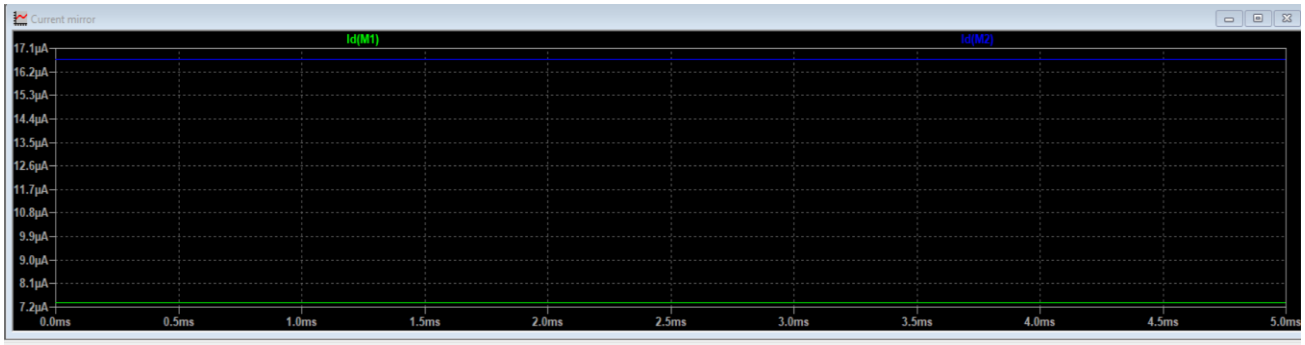
```
iref: id(m1)=7.32763e-06 at 0.004
iout: id(m2)=1.46553e-05 at 0.004
ratio: iout/iref=2
```

By Calculation:

Since, Iout/Iref depends on W and L also Lambda=0 therefore it's value remains same at every instant of time.

2. **When Lambda=0.04**

Simulation:




```
.tran 0 5ms 0 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0.04 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=20u L=5u lambda=0.04 kp=10u gamma=0)
```

Time	Iref	Iout	Iout/Iref By Simulation	Iout/Iref By Calculation
2ms	7.3753uA	16.6777uA	2.26128	2.26159
4ms	7.3753uA	16.6777uA	2.26128	2.26159

Observation Table-4

a. **When Time=2ms**

By Simulation:

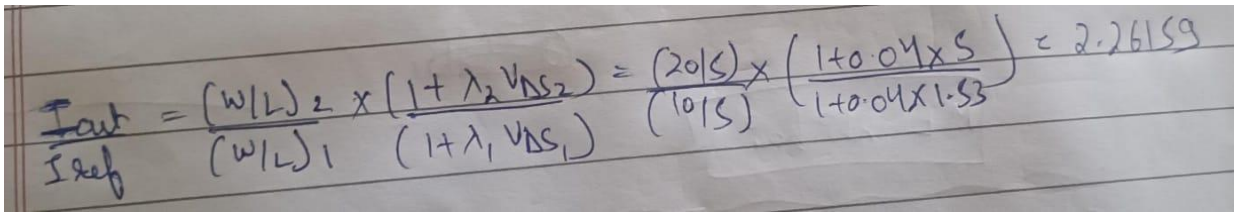
```
.meas iref FIND Id(M1) WHEN time=2ms
.meas iout FIND Id(M2) WHEN time=2ms
.meas ratio param iout/iref
```

```
iref: id(m1)=7.3753e-06 at 0.002
iout: id(m2)=1.66777e-05 at 0.002
ratio: iout/iref=2.26128
```

By Calculation:

By Setting the value of Vdd=5V and DC Operating Point we get the value of Vds2 and Vds1

```
--- MOSFET Transistors ---
Name:          m1          m2
Model:         nmos1       nmos2
Id:            7.38e-06    1.67e-05
Vgs:           1.53e+00    1.53e+00
Vds:           1.53e+00    5.00e+00
```



b. **When Time=4ms**

By Simulation:

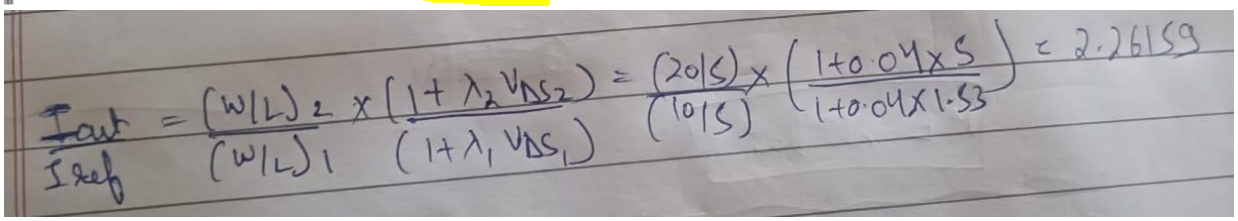
```
.meas iref FIND Id(M1) WHEN time=4ms
.meas iout FIND Id(M2) WHEN time=4ms
.meas ratio param iout/iref
```

```
iref: id(m1)=7.3753e-06 at 0.004
iout: id(m2)=1.66777e-05 at 0.004
ratio: iout/iref=2.26128
```

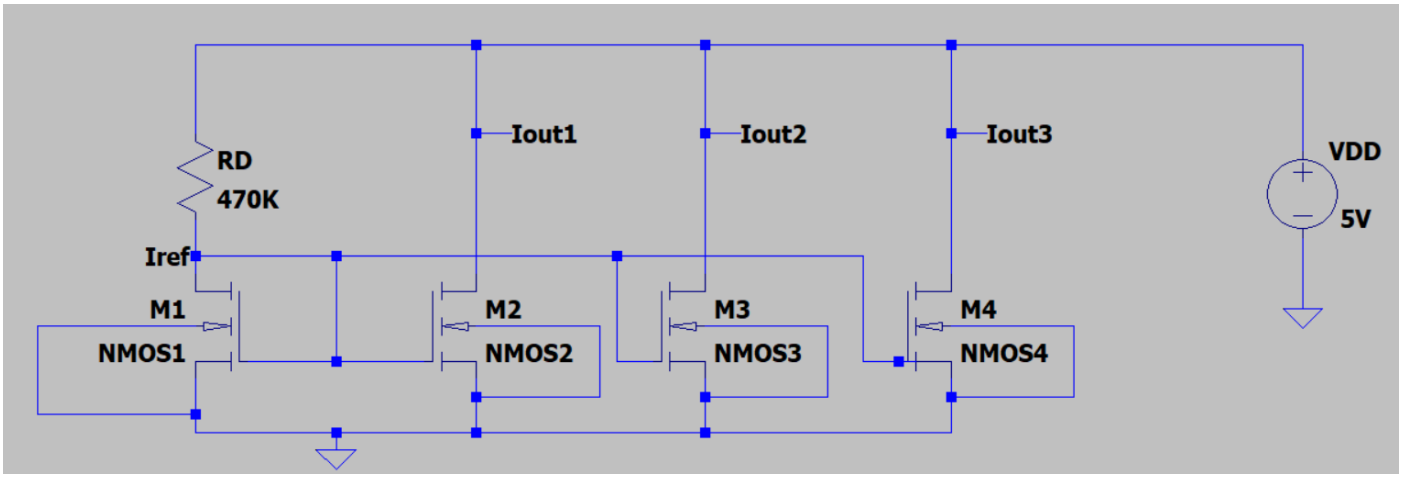
By Calculation:

By Setting the value of Vdd=5V and DC Operating Point we get the value of Vds2 and Vds1

```
--- MOSFET Transistors ---
Name:          m1          m2
Model:         nmos1       nmos2
Id:            7.38e-06    1.67e-05
Vgs:           1.53e+00    1.53e+00
Vds:           1.53e+00    5.00e+00
```



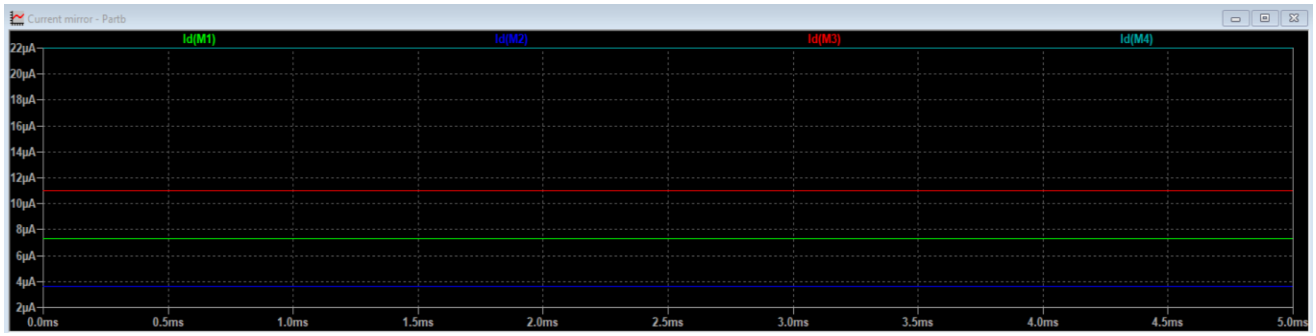
Part B: Schematic



Transient Analysis:

1. **When Lambda=0**

Simulation:




```
.tran 0 5ms 0 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=5u L=5u lambda=0 kp=10u gamma=0)
.model NMOS3 nmos (vto=0.7 W=15u L=5u lambda=0 kp=10u gamma=0)
.model NMOS4 nmos (vto=0.7 W=30u L=5u lambda=0 kp=10u gamma=0)
```

Time	Iref	Iout1	Iout2	Iout3	Iout1/Iref		Iout2/Iref		Iout3/Iref	
					By Simu.	By Cal.	By Simu.	By Cal.	By Simu.	By Cal.
2ms	7.3276 uA	3.66382 uA	10.991 uA	21.982 uA	0.500 001	0.5	1.5	1.5	3	3
4ms	7.3276 uA	3.6638 uA	10.991 uA	21.982 uA	0.500 001	0.5	1.5	1.5	3	3

Observation Table-5

a. **When Time=2ms**

By Simulation:

```
.meas iref FIND Id(M1) WHEN time=2ms
.meas iout1 FIND Id(M2) WHEN time=2ms
.meas iout2 FIND Id(M3) WHEN time=2ms
.meas iout3 FIND Id(M4) WHEN time=2ms
.meas ratio1 param iout1/iref
.meas ratio2 param iout2/iref
.meas ratio3 param iout3/iref
```

```
iref: id(m1)=7.32763e-06 at 0.002
iout1: id(m2)=3.66382e-06 at 0.002
iout2: id(m3)=1.09915e-05 at 0.002
iout3: id(m4)=2.19829e-05 at 0.002
ratio1: iout1/iref=0.500001
ratio2: iout2/iref=1.5
ratio3: iout3/iref=3
```

By Calculation:
Iout1/Iref = (W/L)2/(W/L)1 = (5/5)/(10/5) = 0.5
Iout2/Iref = (W/L)3/(W/L)1 = (15/5)/(10/5) = 1.5
Iout3/Iref = (W/L)4/(W/L)1 = (30/5)/(10/5) = 3

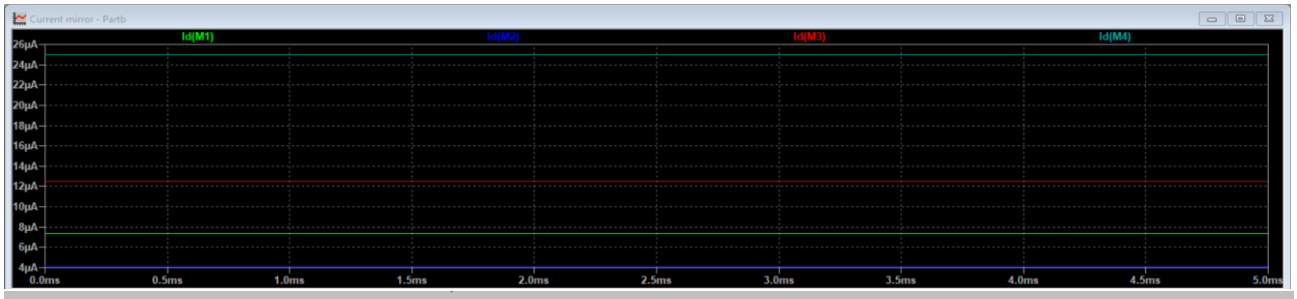
b. **When Time=4ms**
By Simulation:

```
.meas iref FIND Id(M1) WHEN time=4ms
.meas iout1 FIND Id(M2) WHEN time=4ms
.meas iout2 FIND Id(M3) WHEN time=4ms
.meas iout3 FIND Id(M4) WHEN time=4ms
.meas ratio1 param iout1/iref
.meas ratio2 param iout2/iref
.meas ratio3 param iout3/iref
```

```
iref: id(m1)=7.32763e-06 at 0.004
iout1: id(m2)=3.66382e-06 at 0.004
iout2: id(m3)=1.09914e-05 at 0.004
iout3: id(m4)=2.19829e-05 at 0.004
ratio1: iout1/iref=0.500001
ratio2: iout2/iref=1.5
ratio3: iout3/iref=3
```

By Calculation:
Since, Iout1/Iref, Iout2/Iref, Iout3/Iref depends on W and L also Lambda=0 therefore it's value remains same at every instant of time.

2. **When Lambda=0.04**
Simulation:




```
.tran 0 5ms 0 0.1
.model NMOS1 nmos (vto=0.7 W=10u L=5u lambda=0.04 kp=10u gamma=0)
.model NMOS2 nmos (vto=0.7 W=5u L=5u lambda=0.04 kp=10u gamma=0)
.model NMOS3 nmos (vto=0.7 W=15u L=5u lambda=0.04 kp=10u gamma=0)
.model NMOS4 nmos (vto=0.7 W=30u L=5u lambda=0.04 kp=10u gamma=0)
```

Time	Iref	Iout1	Iout2	Iout3	Iout1/Iref		Iout2/Iref		Iout3/Iref	
					By Simu.	By Cal.	By Simu.	By Cal.	By Simu.	By Cal.
2ms	7.3753 uA	4.1694 uA	12.508 uA	25.016 uA	0.565322	0.56539	1.69596	1.6962	3.39192	3.3923
4ms	7.3753 uA	4.1694 uA	12.508 uA	25.016 uA	0.565322	0.56539	1.69596	1.6962	3.39192	3.3923

Observation Table-6

a. When Time=2ms

By Simulation:

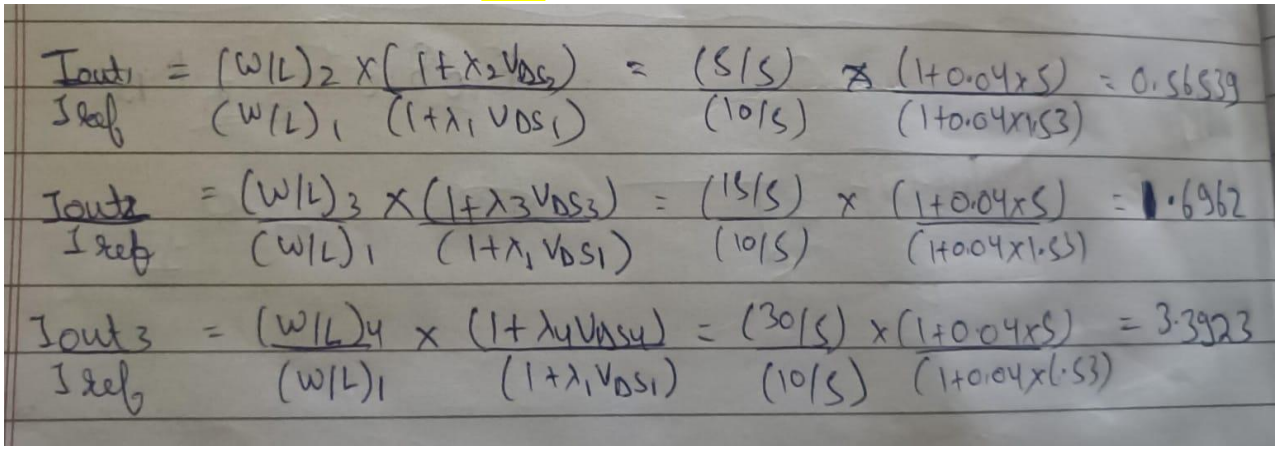
```
.meas iref FIND Id(M1) WHEN time=2ms
.meas iout1 FIND Id(M2) WHEN time=2ms
.meas iout2 FIND Id(M3) WHEN time=2ms
.meas iout3 FIND Id(M4) WHEN time=2ms
.meas ratio1 param iout1/iref
.meas ratio2 param iout2/iref
.meas ratio3 param iout3/iref
```

```
iref: id(m1)=7.3753e-06 at 0.004
iout1: id(m2)=4.16942e-06 at 0.002
iout2: id(m3)=1.25082e-05 at 0.002
iout3: id(m4)=2.50165e-05 at 0.002
ratio1: iout1/iref=0.565322
ratio2: iout2/iref=1.69596
ratio3: iout3/iref=3.39192
```

By Calculation:

By Setting the value of Vdd=5V and DC Operating Point we get the value of Vds4, Vds3, Vds2 and Vds1.

Name:	m1	m2	m3	m4
Model:	nmos1	nmos2	nmos3	nmos4
Id:	7.38e-06	4.17e-06	1.25e-05	2.50e-05
Vgs:	1.53e+00	1.53e+00	1.53e+00	1.53e+00
Vds:	1.53e+00	5.00e+00	5.00e+00	5.00e+00



b. When Time=4ms

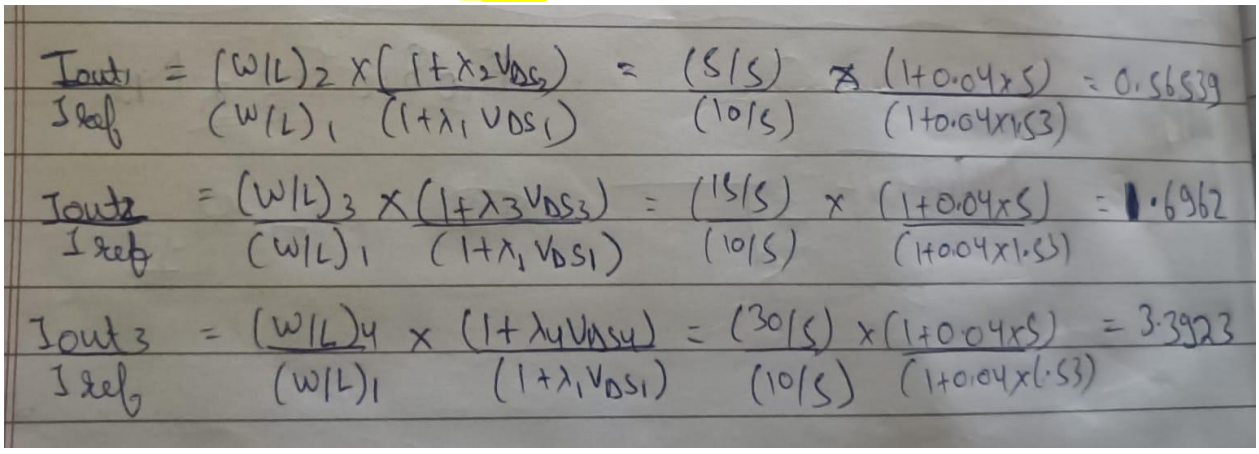
```
.meas iref FIND Id(M1) WHEN time=4ms
.meas iout1 FIND Id(M2) WHEN time=4ms
.meas iout2 FIND Id(M3) WHEN time=4ms
.meas iout3 FIND Id(M4) WHEN time=4ms
.meas ratio1 param iout1/iref
.meas ratio2 param iout2/iref
.meas ratio3 param iout3/iref
```

```
iref: id(m1)=7.3753e-06 at 0.004
iout1: id(m2)=4.16942e-06 at 0.002
iout2: id(m3)=1.25082e-05 at 0.002
iout3: id(m4)=2.50165e-05 at 0.002
ratio1: iout1/iref=0.565322
ratio2: iout2/iref=1.69596
ratio3: iout3/iref=3.39192
```

By Calculation:

By Setting the value of Vdd=5V and DC Operating Point we get the value of Vds4, Vds3, Vds2 and Vds1.

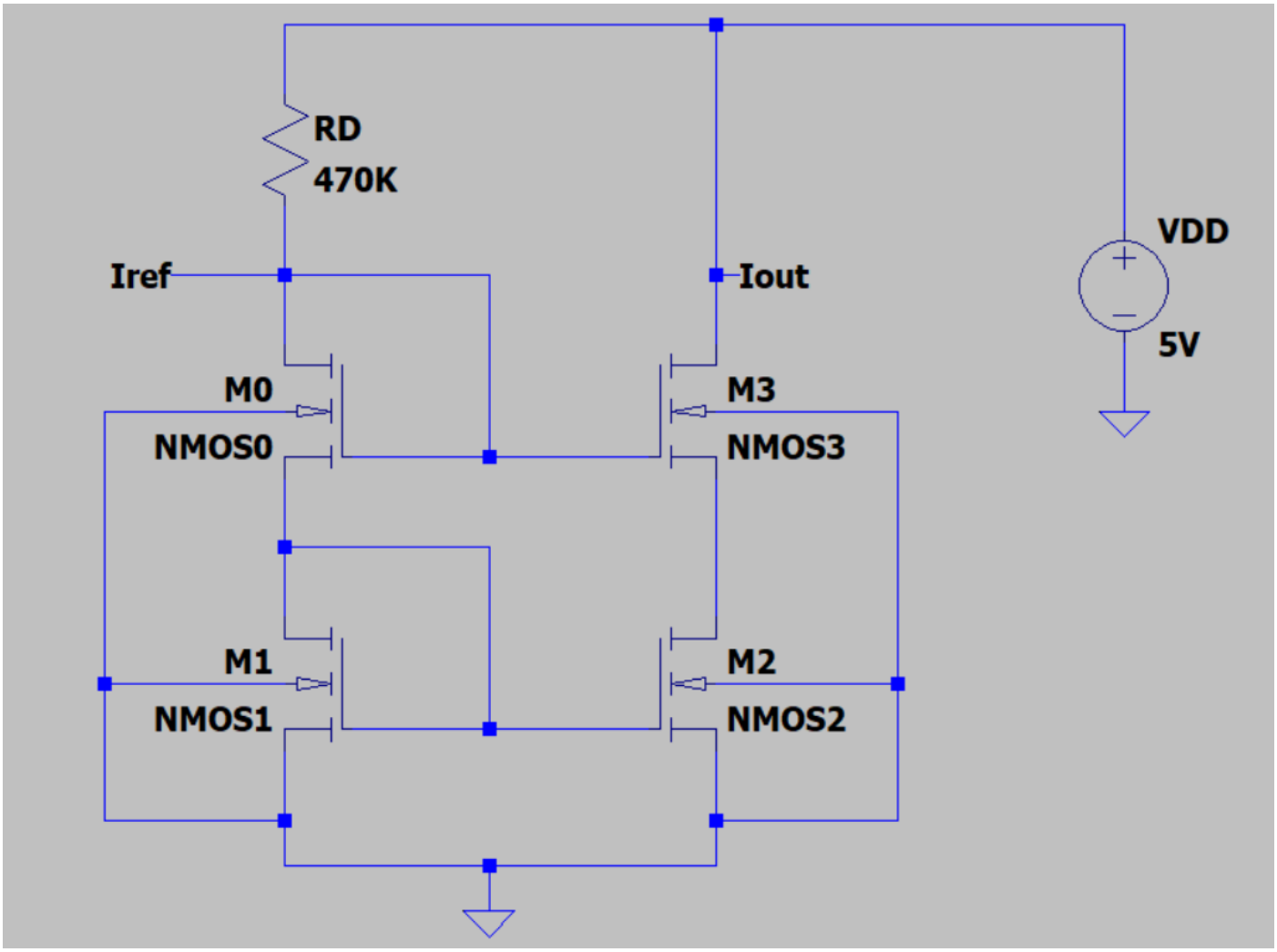
Name:	m1	m2	m3	m4
Model:	nmos1	nmos2	nmos3	nmos4
Id:	7.38e-06	4.17e-06	1.25e-05	2.50e-05
Vgs:	1.53e+00	1.53e+00	1.53e+00	1.53e+00
Vds:	1.53e+00	5.00e+00	5.00e+00	5.00e+00



Part C: Cascoded Current Mirror

In Cascoded Current Mirror, we take Gamma as non-zero because the Source of the Transistor M1 and M2 is not ground but it is lifted up by the Vds of the Transistor M0 and M3 that's why there is some body effect due to which gamma is not zero which is not so in the non-cascoded current mirror.

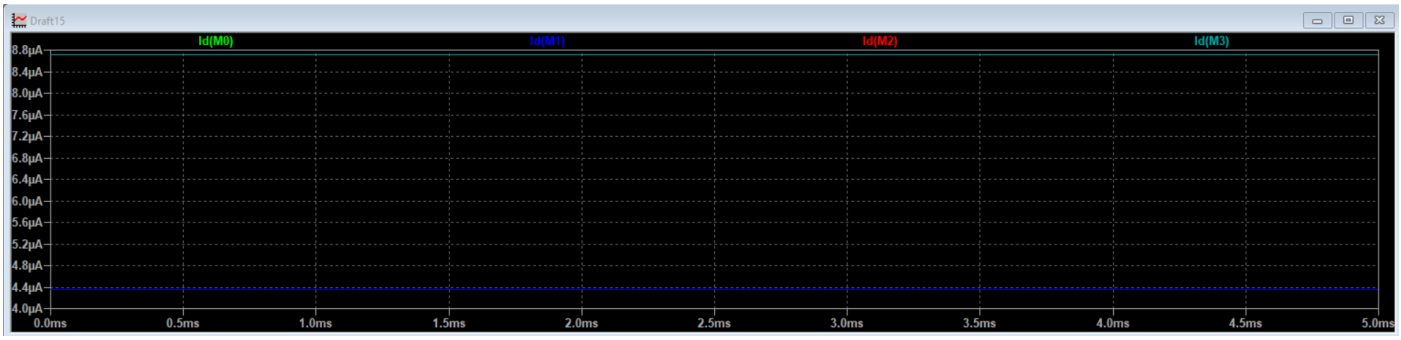
Schematic:



Transient Analysis:

When Lambda=0.04:

Simulation:



Id(M0) == Id(M1) ; Id(M2)==Id(M3) because they are connected in series.

```
.tran 0 5ms 0 0.1ms
.model nmos0 nmos (vto=0.7, kp=10u, Lambda=0.04, gamma=0.4, W=10u, L=5u)
.model nmos1 nmos (vto=0.7, kp=10u, Lambda=0, gamma=0.4, W=10u, L=5u)
.model nmos2 nmos (vto=0.7, kp=10u, Lambda=0, gamma=0.4, W=20u, L=5u)
.model nmos3 nmos (vto=0.7, kp=10u, Lambda=0.04, gamma=0.4, W=20u, L=5u)
```

Time	Iref	Iout	Iout/Iref By Simulation	Iout/Iref By Calculation
2ms	4.36006uA	8.72014uA	2	2
4ms	4.36007uA	8.72013uA	2	2

Observation Table-7

a. **When time=2ms**

By Simulation:

```
.meas iref FIND Id(M0) WHEN time=2ms
.meas iout FIND Id(M3) WHEN time=2ms
.meas ratio param iout/iref
```

```
iref: id(m0)=4.36007e-06 at 0.002
iout: id(m3)=8.72014e-06 at 0.002
ratio: iout/iref=2
```

By Calculation:

Iout/Iref = (W/L)3/(W/L)0 = (20/5)/(10/5) = 2

b. **When time=4ms**

By Simulation:

```
.meas iref FIND Id(M0) WHEN time=4ms
.meas iout FIND Id(M3) WHEN time=4ms
.meas ratio param iout/iref
```

```
iref: id(m0)=4.36007e-06 at 0.004
iout: id(m3)=8.72013e-06 at 0.004
ratio: iout/iref=2
```

By Calculation:

Iout/Iref = (W/L)3/(W/L)0 = (20/5)/(10/5) = 2

In a cascoded current mirror, we use an extra transistor (like M1 and M2) to keep the VDS of the mirroring transistor (M3) approximately equal to that of the reference (M0).
That's why factor of lambda got cancelled even when lambda is not zero. Which is not so in the non-cascoded current mirror when lambda is not zero because the value of Vds(M0) and Vds(M3) could vary acc. to output loading.