DESIGN OF LOW COST LOW POWER INTEGRATED (LED) DRIVER

- **Introduction**
  (Heba Abd Al - Moniem)
- **Boost Converter & DCM Mode**
  (Aya Gebreel)
- **Power Stage of System**
  (Mahmoud Nassary)
- **Control of System**
  (Noha Ibrahim)
- **IC Design**
  (Aya Bakr & Mahmoud Nassary)
- **Layout**
  (Aya Gebreel & Heba Abd Al – Moniem)

❖ Design of Low cost Low power Integrated (LED) drive

Project steps:-

Project goal is to replace a lamp with low cost low power integrated LED drive.

- Choose the lamp that will be replaced.
- Design the system of LED Drive and make it in integrated circuit
- Made the design of the IC and the layout of it.

❖ Disadvantages of Halogen lamp

- 1-As with incandescent bulbs, percent of the energy used by halogen bulbs is given off as heat instead of light. So using too hot of a bulb creates a fire risk.
- 2- Low lifetime 3000 hour (4 months).
- 3- High power consuming 50w.

❖ Advantages of led lamp

- Energy Efficiency
  LEDs are highly efficient. an LED circuit will approach 80% efficiency
- Long Life
  Some LEDs are projected to produce a long service life of about 100,000 hours (10 years)
- Range of Colors
  LEDs are available in a range of colors (see above), including white light.
- No UV Emissions/Little Infrared
  LEDs produce no UV radiation and little heat, making them ideal for illuminating objects, such as works of art, that are sensitive to UV light.

Cont.

- Durable
  LEDs are highly rugged. They feature no filament that can be damaged due to shock and vibrations. They are subject to heat, however, and being overdriven by the power supply.
- Small Size/Design Flexibility
  A single LED is very small and produces little light overall
- SAFTY
- Improved safety may be one of the most important benefits of LED lighting. LED lights generate virtually no heat
- Lights instantly
- Can be easily dimmed

❖ Two options are typically available for replacements

- Replace only the halogen lamp with an integrated LED lamp. In this case, the LED product—combining LED package(s), optics, thermal management, and driver—must both conform to the MR16 form factor and operate in conjunction with the transformer built in to the track head or remotely powering the low-voltage track.
- Compatibility should be carefully evaluated, and following the recommended practices provided in this fact sheet is strongly encouraged. Dimming presents an added concern; if it can be avoided, finding compatible products may be more straightforward.

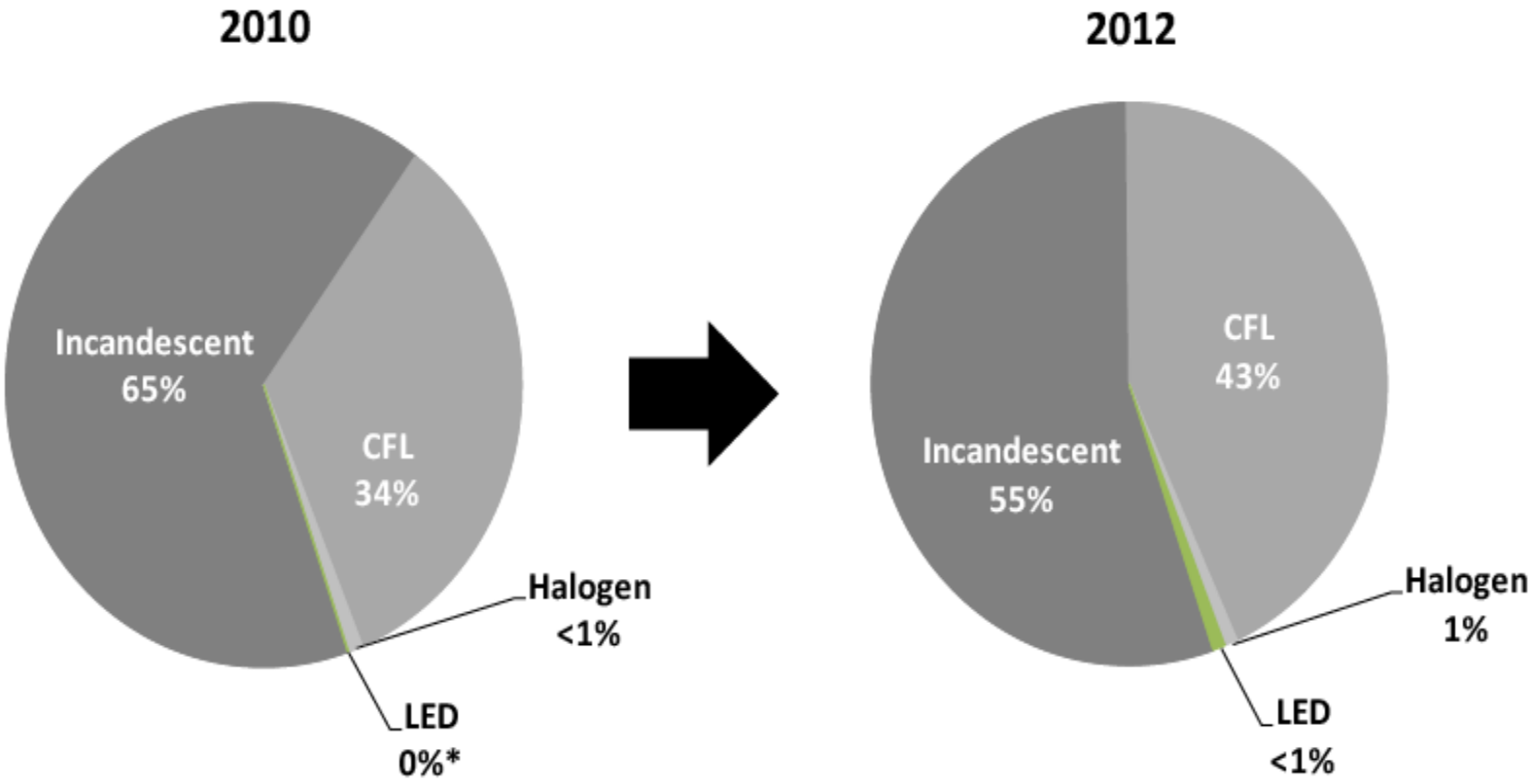
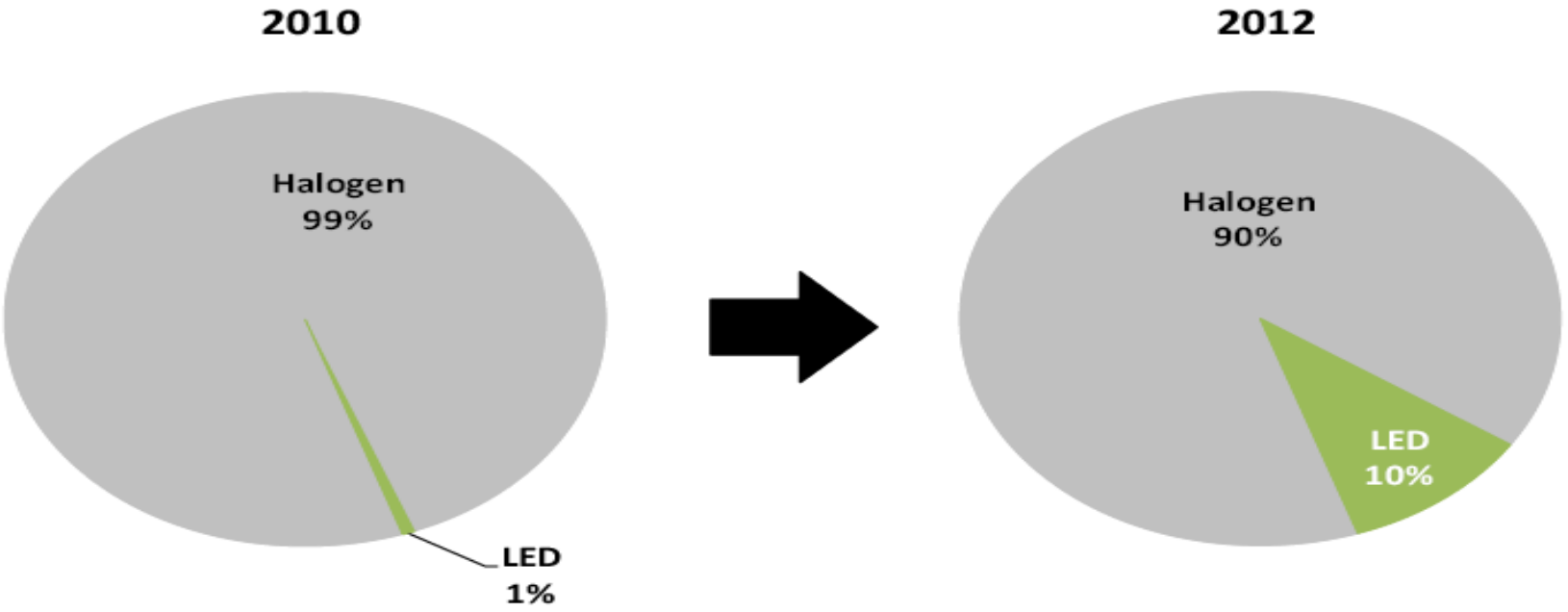


Fig 1. Values less than 0.1% are considered negligible

Cont.

- As seen in Figure 1, from 2010 to 2012 the installed base of incandescent A-type lamps decreased from 65 percent to 55 percent, while CFLs increased from 34 percent in 2010 to 43 percent in 2012.
- While nearly 20 million LED A-type lamps are installed in the U.S. this is less than one percent of the total A-type lamp installed base.



MR16 Lamps	LED Installed Base Units millions	Total Energy Consumption Source– tBtu (Site – TWh)	LED Energy Savings Source– tBtu (Site – TWh)	Potential LED Energy Savings Source– tBtu (Site – TWh)
2012	4.8	70 (6.7)	3.7 (0.4)	65 (6.2)

❖ Cost Comparison between LEDs, CFLs and Incandescent light bulbs

	LED	CFL	Incandescent
Light bulb projected lifespan	50,000 hour 5years ,9monthes	10,000 hour 1 year ,month	1,200 hour Month ,10 days
Watts per bulb (equiv. 60 watts)	10	14	60
Cost per bulb	$35.95	$3.95	$1.25
KWh of electricity used over 50,000 hours	300 500	700	3000
Cost of electricity (@ 0.10per KWh)	$50	$70	$300
Bulbs needed for 50k hours of use	1	5	42
Equivalent 50k hours bulb expense	$35.95	$19.75	$52.50
Total cost for 50k hours	$85.75	$89.75	$352.50

❖ Applications of LED

- LED backlighting in large LCD
- panels; LCD-TV and notebooks
- General lighting and illumination
- Automotive lighting
- Flashlights
- Freezer Case LED Lighting
- Status lights on electronic devices of all kinds
- Decorative lighting strings (both indoor and outdoor)
- Traffic lights
- Outdoor lighting fixtures for parking lots, streets, and parks
- Retail display lighting
- Home lighting applications such as recessed down-lights and under-cabinet lights

❖ XLamp XP-G LED lamp

- **The Lampe choose:-**

From Cree company

Fig 2. XLamp XP-G LED lamp

❖ Specification

- Available in white, outdoor white and 80-CRI, 85-CRI and -CRIwhite
- ANSI-compatible chromaticity bins
- Maximum drive current:1500 mA
- Low thermal resistance: 4 °C/W
- Wide viewing angle: 125°
- Unlimited floor life at≤ 30 ºC/85% RH
- Electrically neutral thermal path
- RoHS- and Reach-compliant
- UL-recognized component(E349212)
- Efficiency 102lum/watte
- 367 lumens

❖ Block Diagram of System

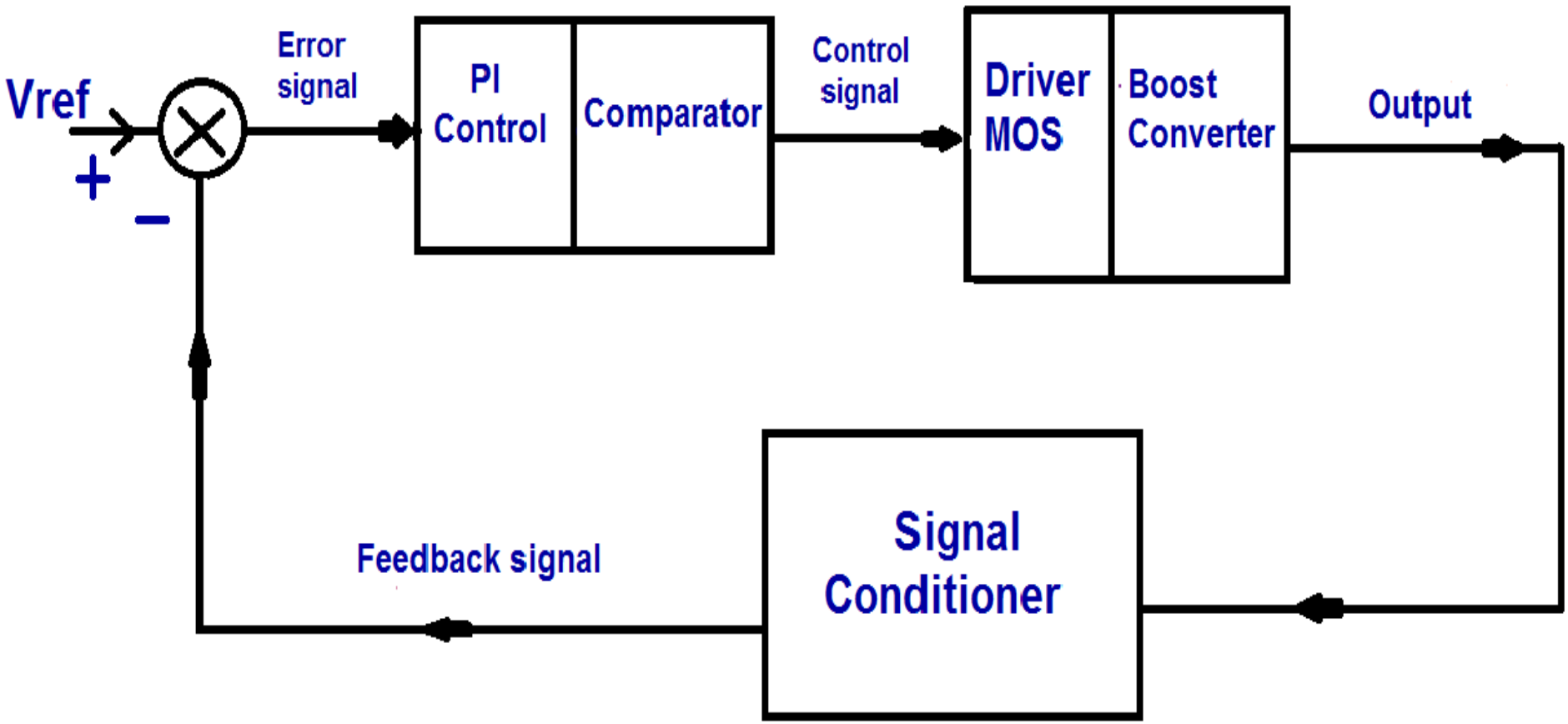


Fig3. Block Diagram of System

❖ Boost converter

- As the LED lamps are not operate from AC input power supply directly . Therefore, an AC/DC converter is needed to drive the LED lamp.
- We choose the boost converter , A boost converter (step-up converter) is **a AC-to-DC** power converter with an output voltage greater than its input voltage

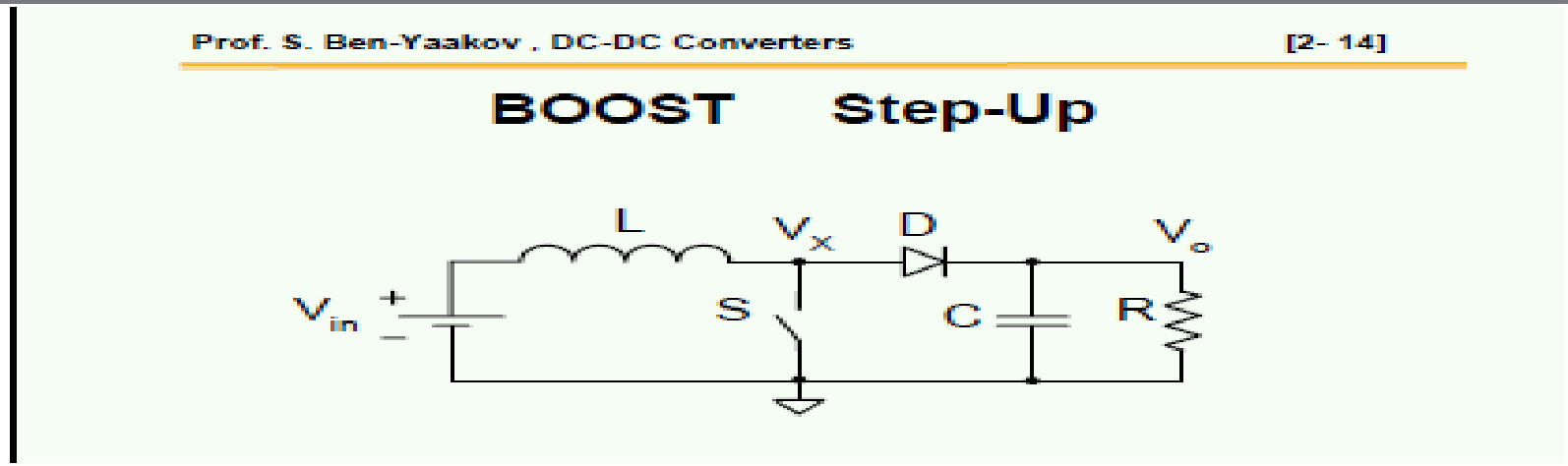


Fig4. Boost converter

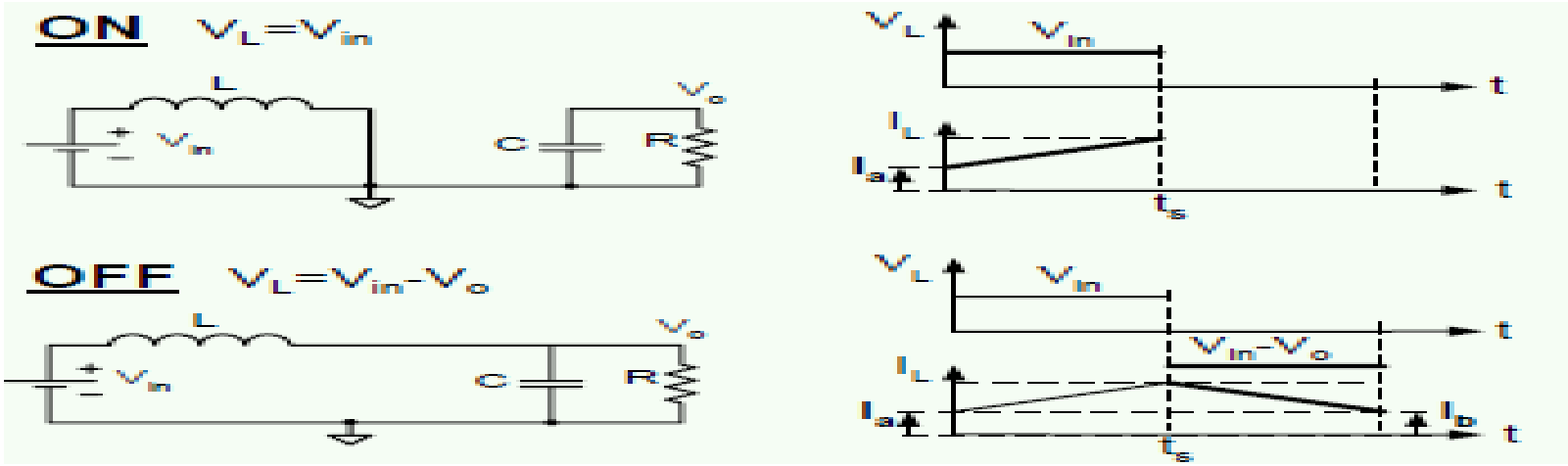


Fig5. Operation modes of boost

❖ Advantages of Boost Converter

- The converter can easily be designed to operate at efficiencies greater than %.
- Both the MOSFET and LED string are connected to a common ground. This simplifies sensing of the LED current, unlike the buck converter where we have to choose either a high side MOSFET driver or a high side current sensor.

❖ DCM mode

- In this project the boost converter is operate in DCM (Discontinuous conduction mode) because a converter behaves as resistor emulator where the line current naturally follows the line voltage and provides a high power factor that near to one.

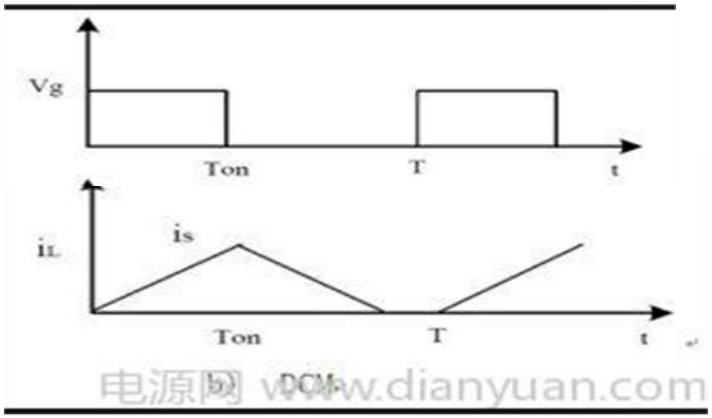


Fig6. DCM Mode

❖ DCM Advantages

- Near unity power factor and using constant switching frequency
- Simple PWM control and only one control loop is needed
- Cheap and easy to implement.

❖ System Design

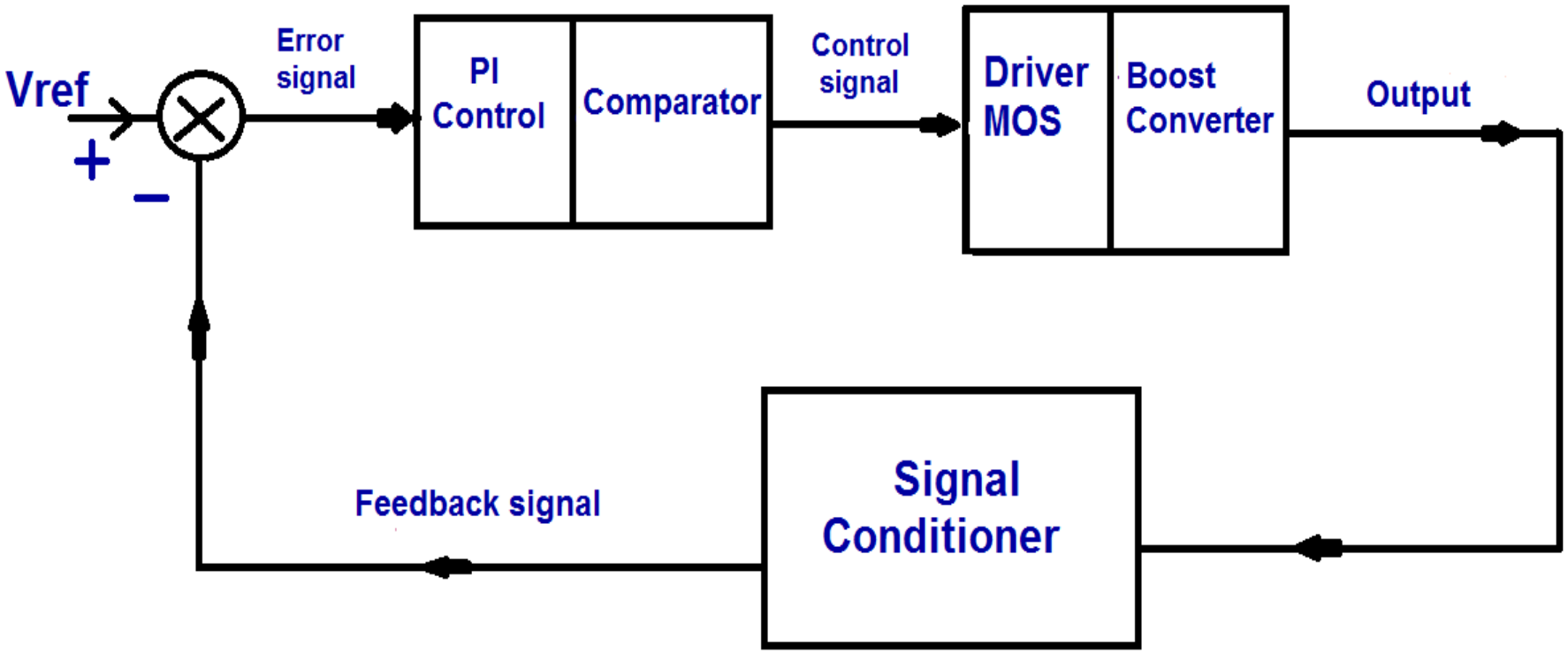


Fig 7. Block Diagram of System

❖ System design

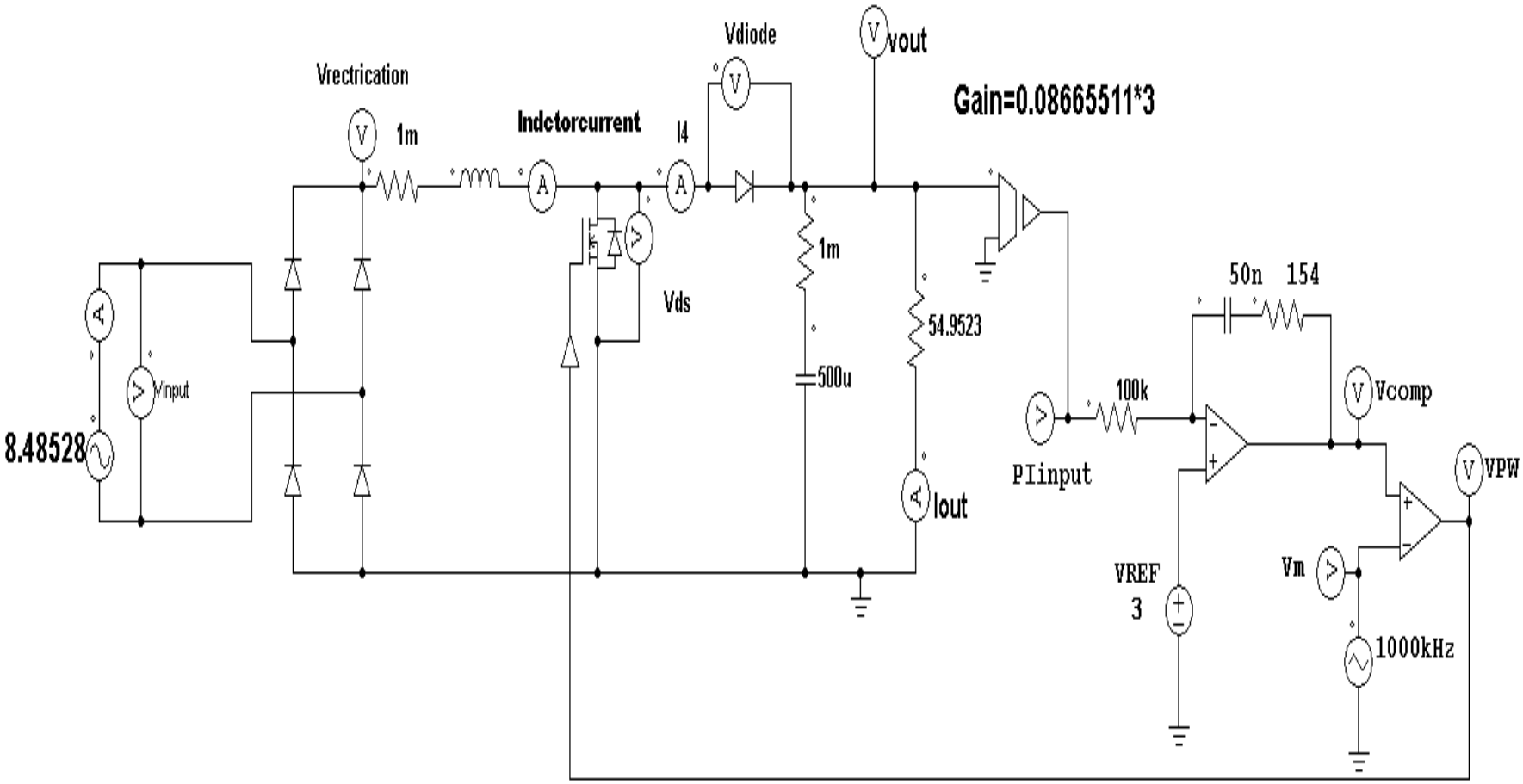
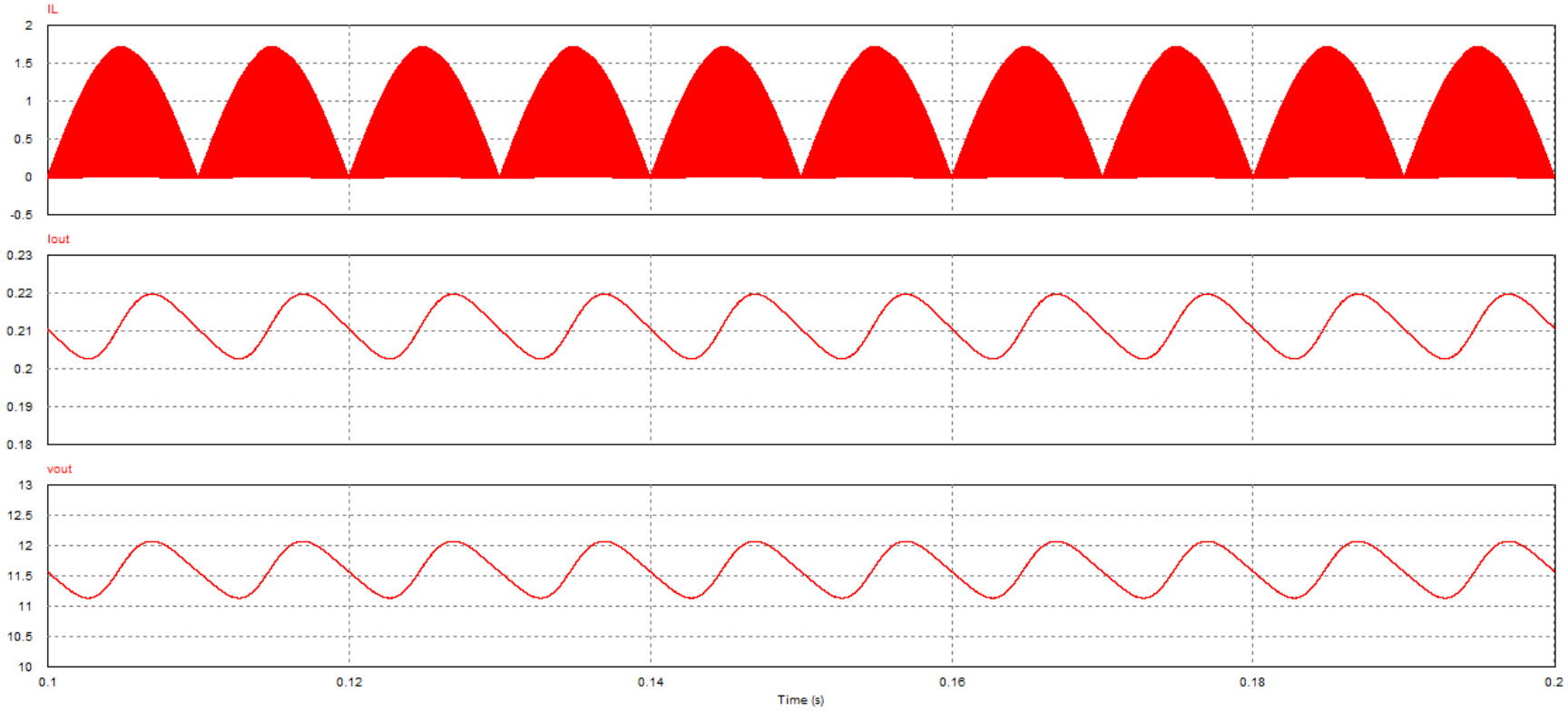


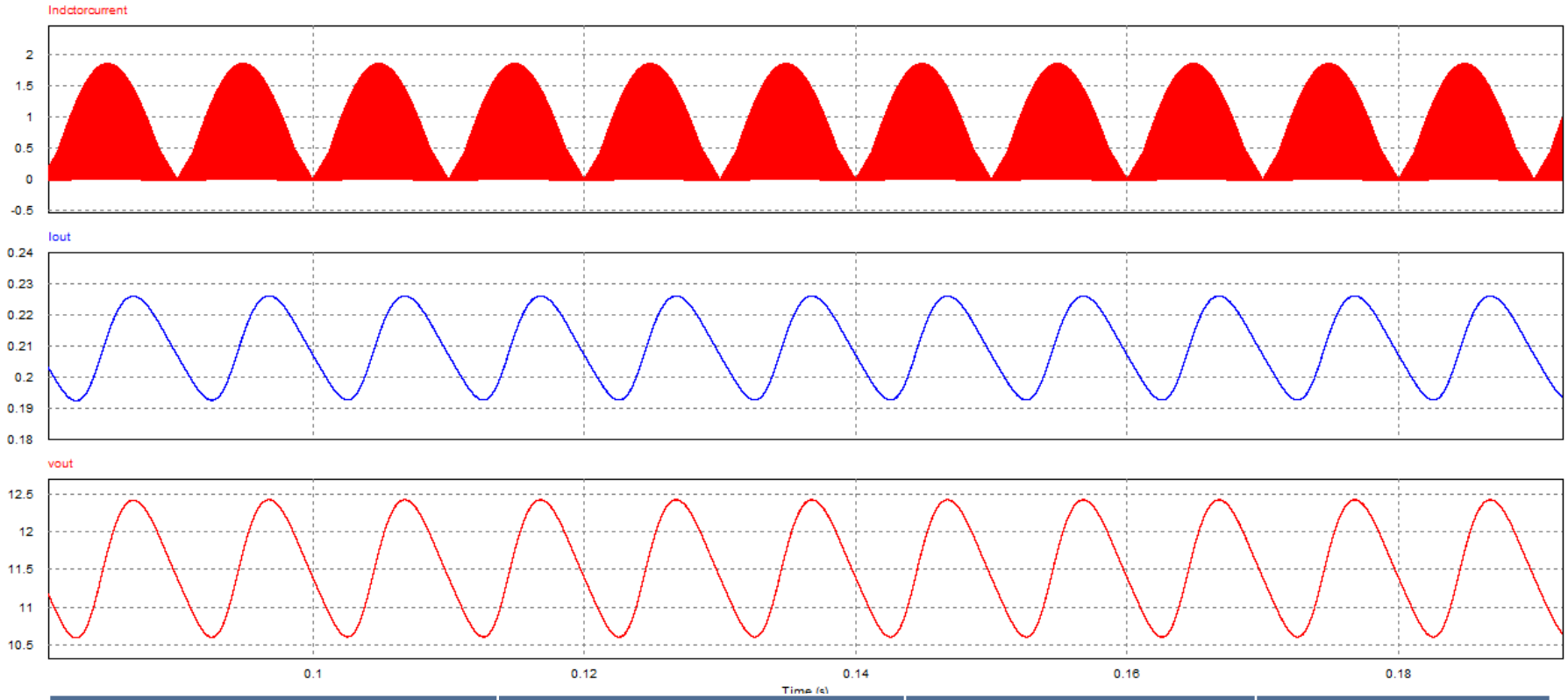
Fig 8.System with feedback

❖ Closed loop output in nominal value



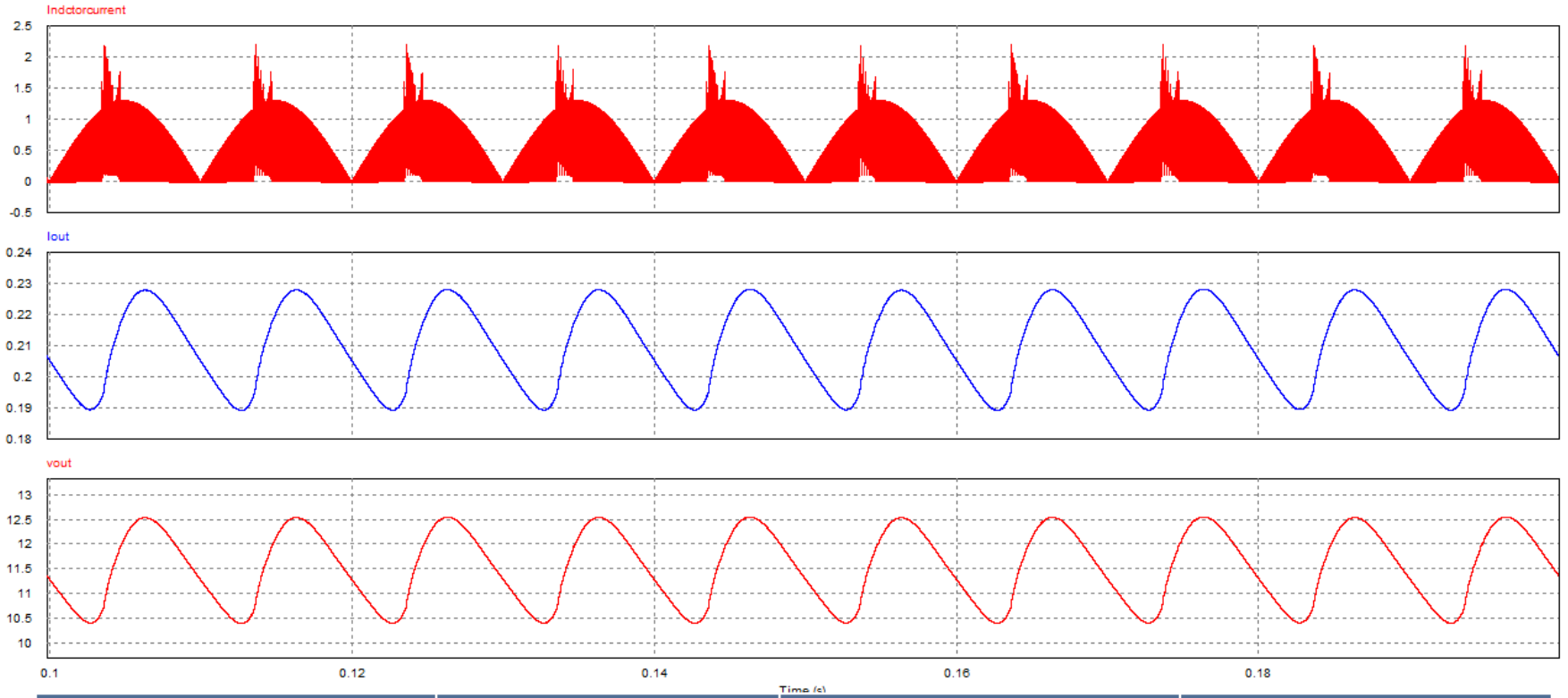
signal	Max	Min	Mean	Ripple
Inductor current (A)	1.86	0	0.33	1.86
Iout (A)	0.22	0.19	0.21	0.02
Vout (V)	12.11	10.65	11.54	1.45

❖ When make variation -20% in vin (vin=6.78 VPTP)



Signal	Max	Min	Mean
Inductor current (A)	1.86	0	0.35
Iout (A)	0.22	0.192	0.20
Vout (V)	12.43	10.583	11 .539

❖ When make variation +20% in vin (vin= 10.182 VPTP)



signal	Max	Min	Mean
Inductor current (A)	0.22	0	0.295
Iout (A)	0.228	0.1893	0.209
Vout (V)	12.54	10.40	11.539

❖ System output comparison

signal	Max	Min	Mean	Ripple
Inductor current (A)	1.86	0	0.33	1.86
Iout (A)	0.22	0.19	0.21	0.02
Vout (V)	12.11	10.65	11.54	1.45

Nominal value

Signal	Max	Min	Mean
Inductor current (A)	1.86	0	0.35
Iout (A)	0.22	0.192	0.20
Vout (V)	12.43	10.583	11 .539

Variation -20% in Vin

signal	Max	Min	Mean
Inductor current (A)	0.22	0	0.295
Iout (A)	0.228	0.1893	0.209
Vout (V)	26	10.40	11.539

Variation +20% in Vin

❖ Why controller?

❖Our System consists of two stage

- Power stage circuit
- Control circuit

❖The Control circuit avoid

- The change in output voltage
- Characteristics of led

❖ **The out of control circuit is the input to power stage**

❖ Control circuit consist of

- Pi control
- Comparator

❖ Control types

- P (proportional control)
- PI (proportional with integral control)
- PID (proportional-integral-derivative control)

❖ Comparison between types of controller

- **P** control
  - The most easy in implementation
  - very simple one
  - But it can't arrive to error equal zero
- **PI** control
  - Can arrive to zero error
  - Have overshoot
  - Take some time to arrive zero error
  - Easy and simple
- **PID** control
  - Can arrive to zero error in high speed
  - No over shoot
  - But it very hard in implementation and very complex

❖ Choosing of PI

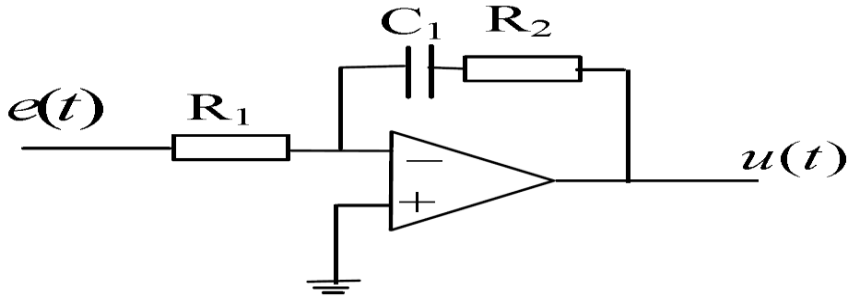
- We can’t use P control
  - Because It can’t arrive to zero error.

- We choose PI control because of :
  - It can arrive to zero error
  - It is simple
  - It is Easy in implementation

- **We develop in pi control to get small overshoot**

$$\frac{U(s)}{E(s)} = K_P + \frac{K_I}{s}$$

$$\frac{U(s)}{E(S)} = -\frac{\frac{1}{sC_1} + R_2}{R_1}$$



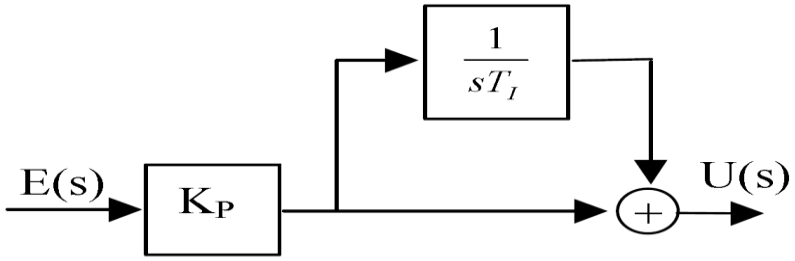


Fig 10. The PI Control Circuit

❖ PI Implementation

- **Tuning PI Controllers**

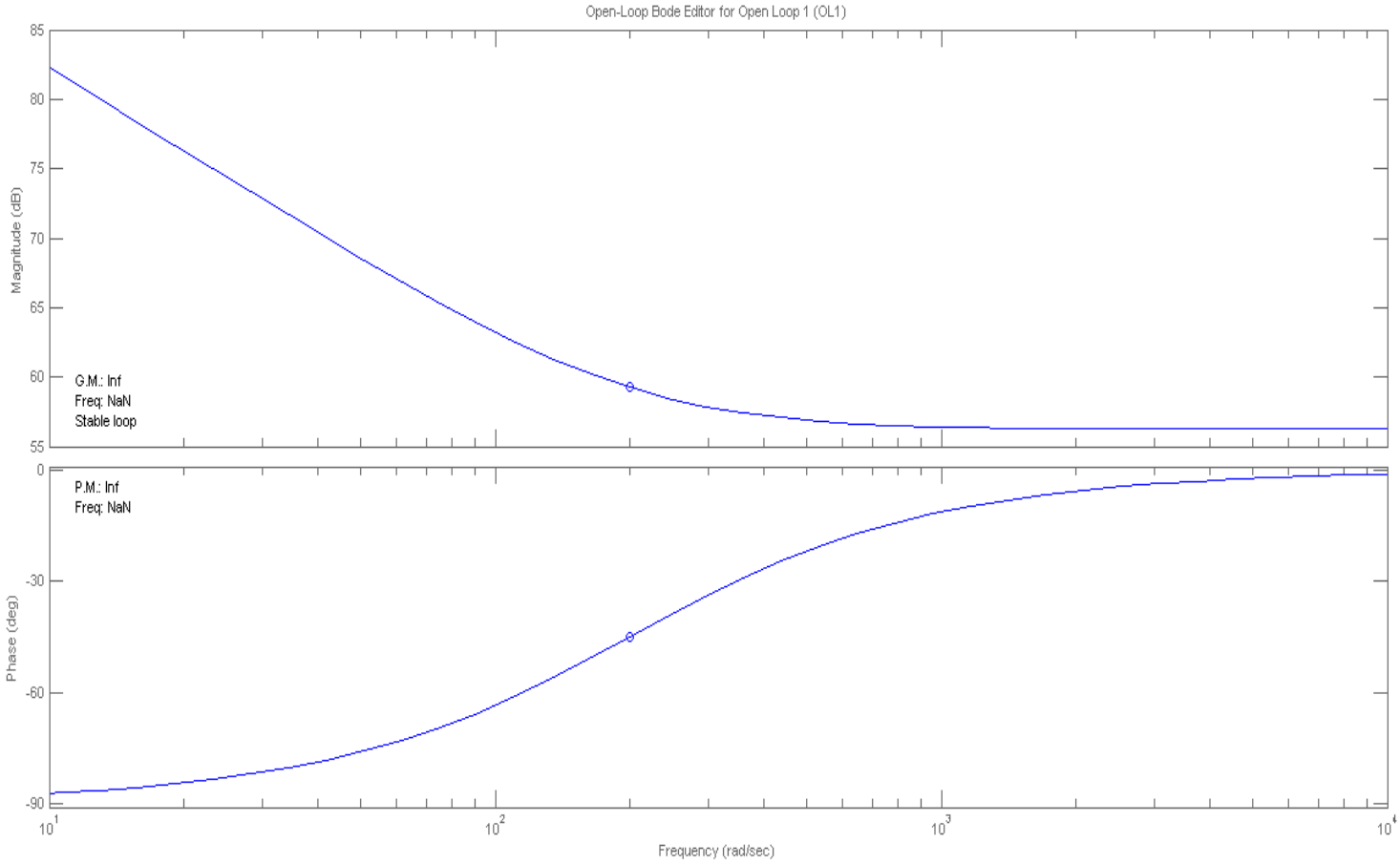
General approach to tuning:

1. Initially have no integral gain (TI large)

2. Increase KP until get satisfactory response

3. Start to add in integral (decreasing TI) until the steady state error is removed in satisfactory time (need to reduce KP)

❖Bode diagram in MATLAB



❖Block diagram of system

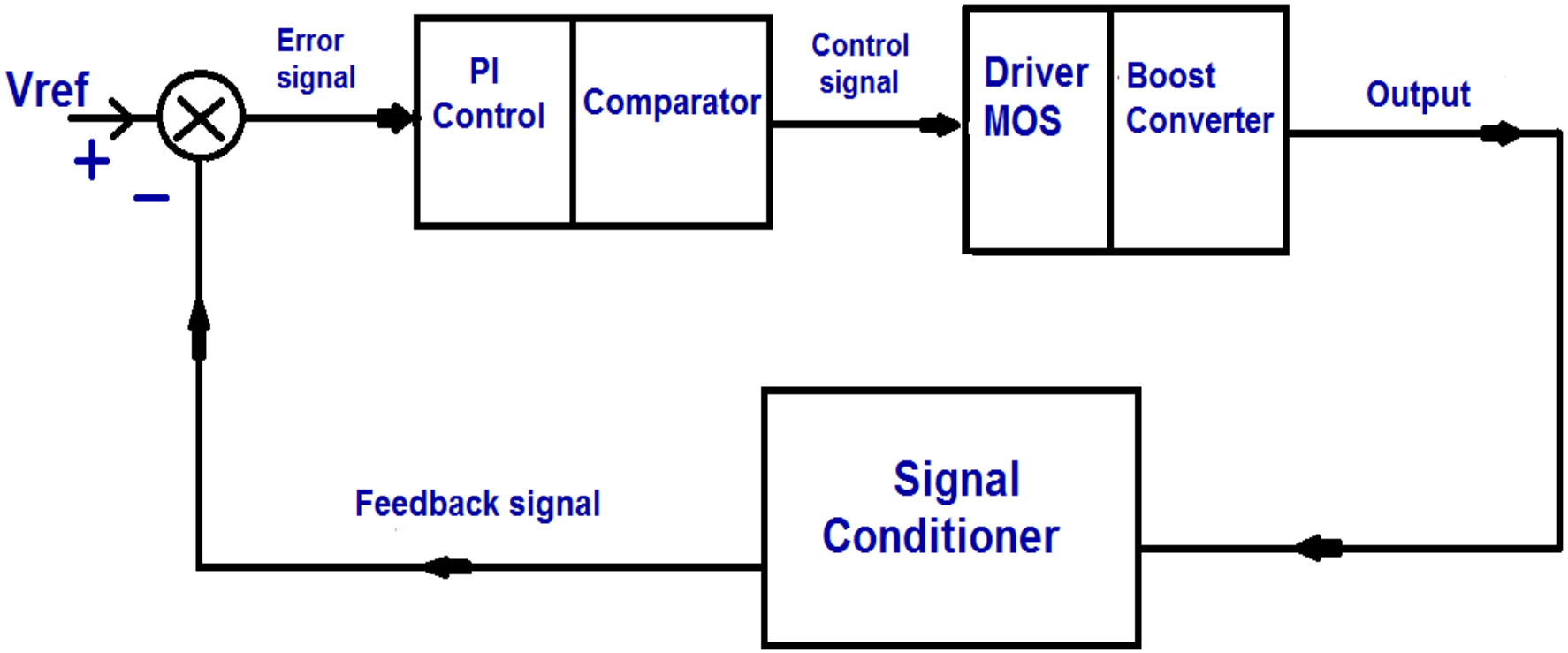
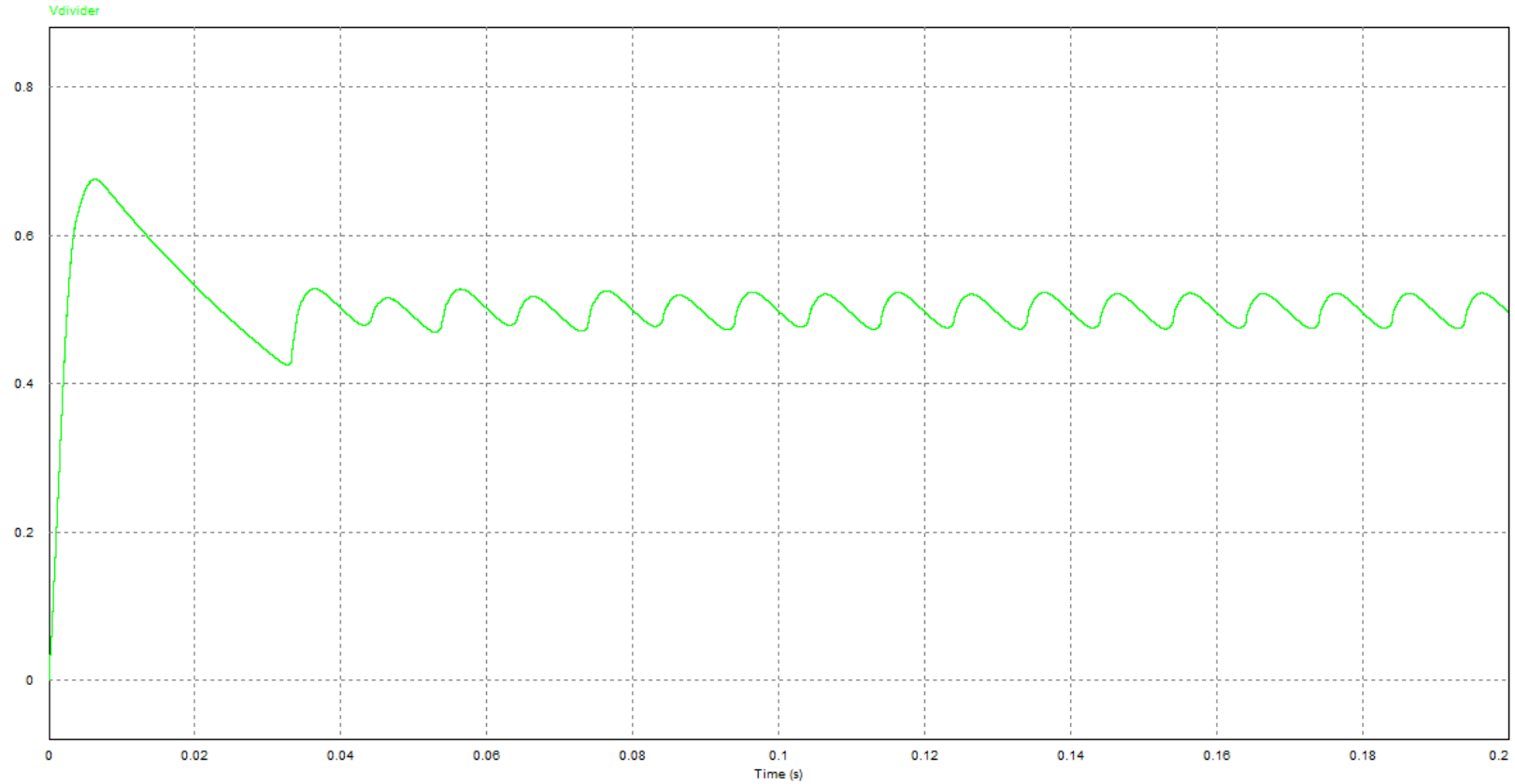


Fig 11. Block Diagram of System

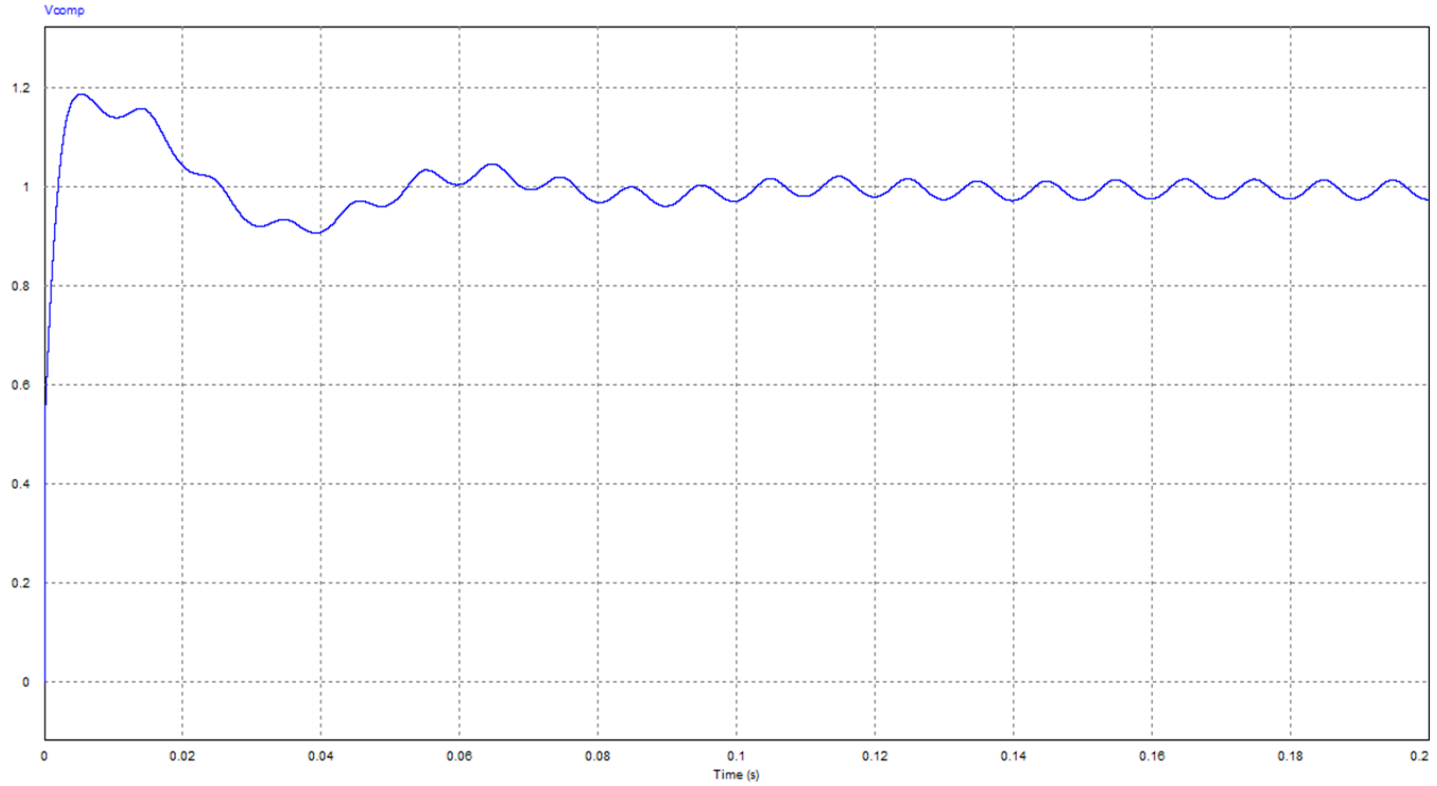
❖ Input signal to PI control



Voltage

Time

❖ Out put signal from PI control



Vcomp

Time

Fig 12. Control Signal

❖Comparator

- The signal which out from pi control is the input to comparator
- This signal compare with saw tooth signal to

Get duty cycle as feed back to power stage circuit

Duty cycle change by change in output voltage of power stage circuit

- We use gate drive to operate MOSFET in boost converter

❖ Pulse width modulation circuit

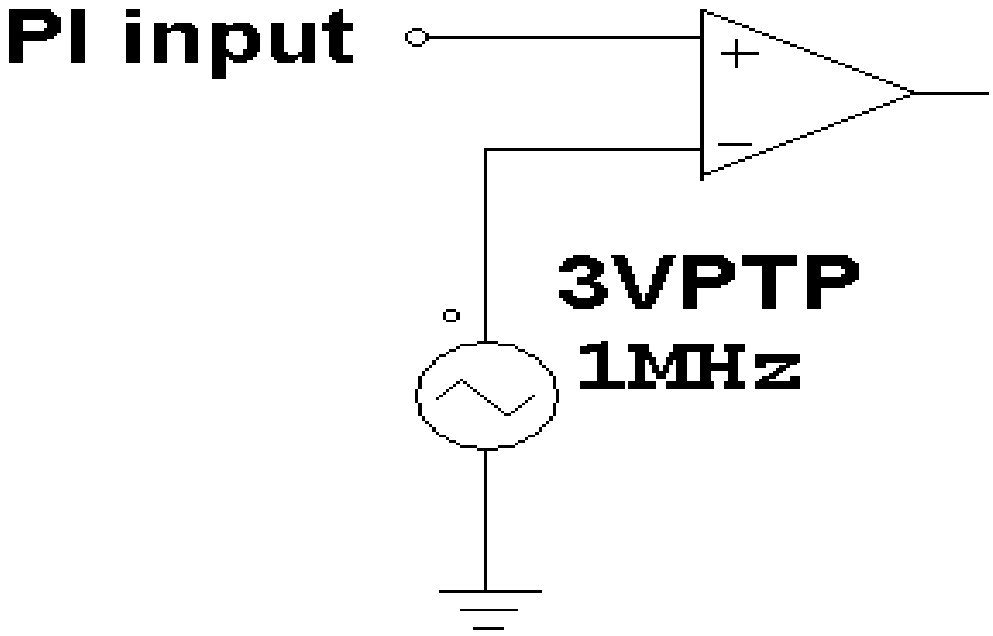


Fig 13. pulse width modulation circuit

❖ Out put voltage from comparator

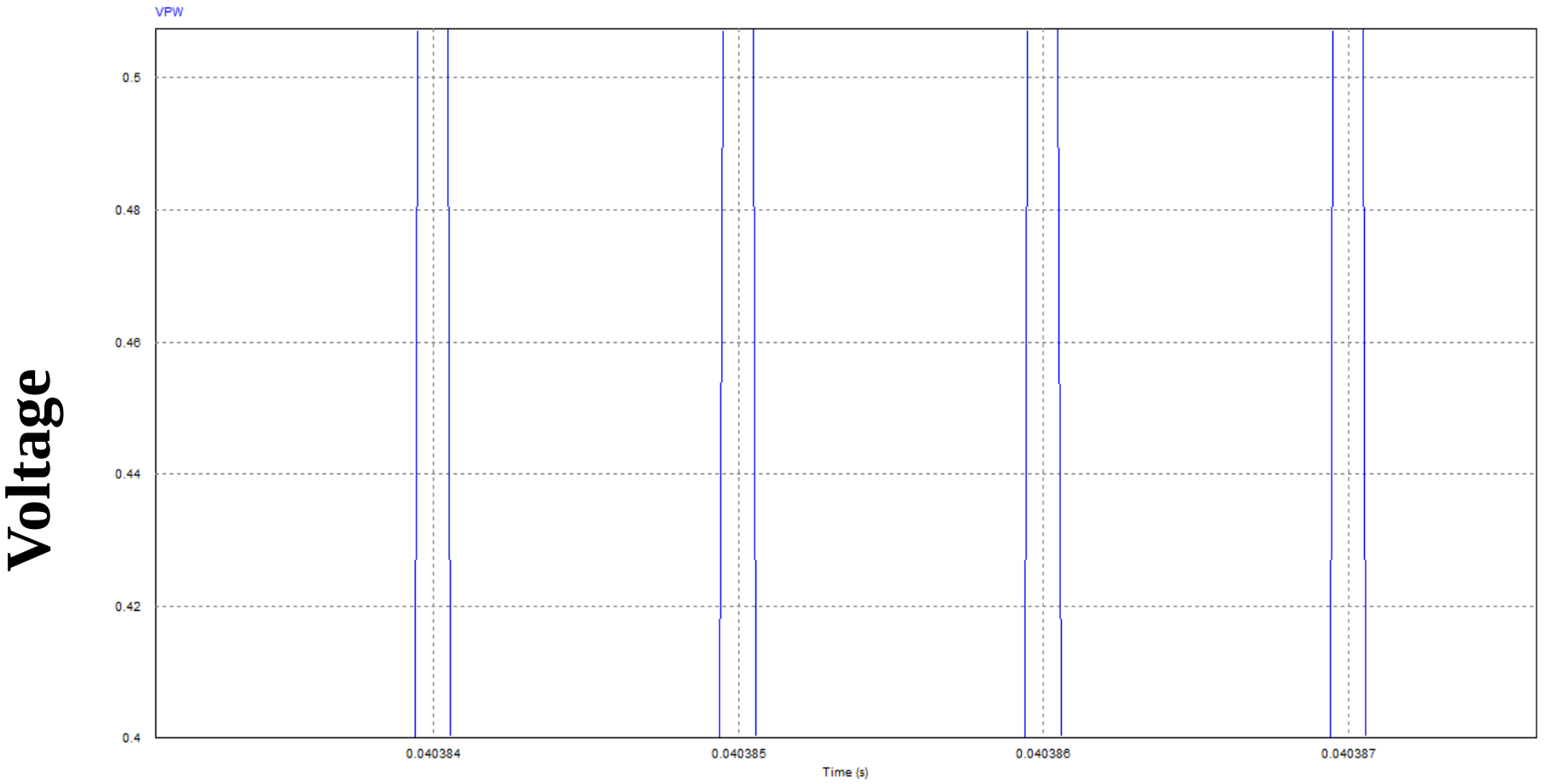


Fig 14. Output Voltage of comparator

IC Design

- **Design of :**
  - Operational Amplifier
  - Current Mirror
  - Differential Amplifier
  - Oscillator
  - Gate Drive
  - Power FET

❖ System design

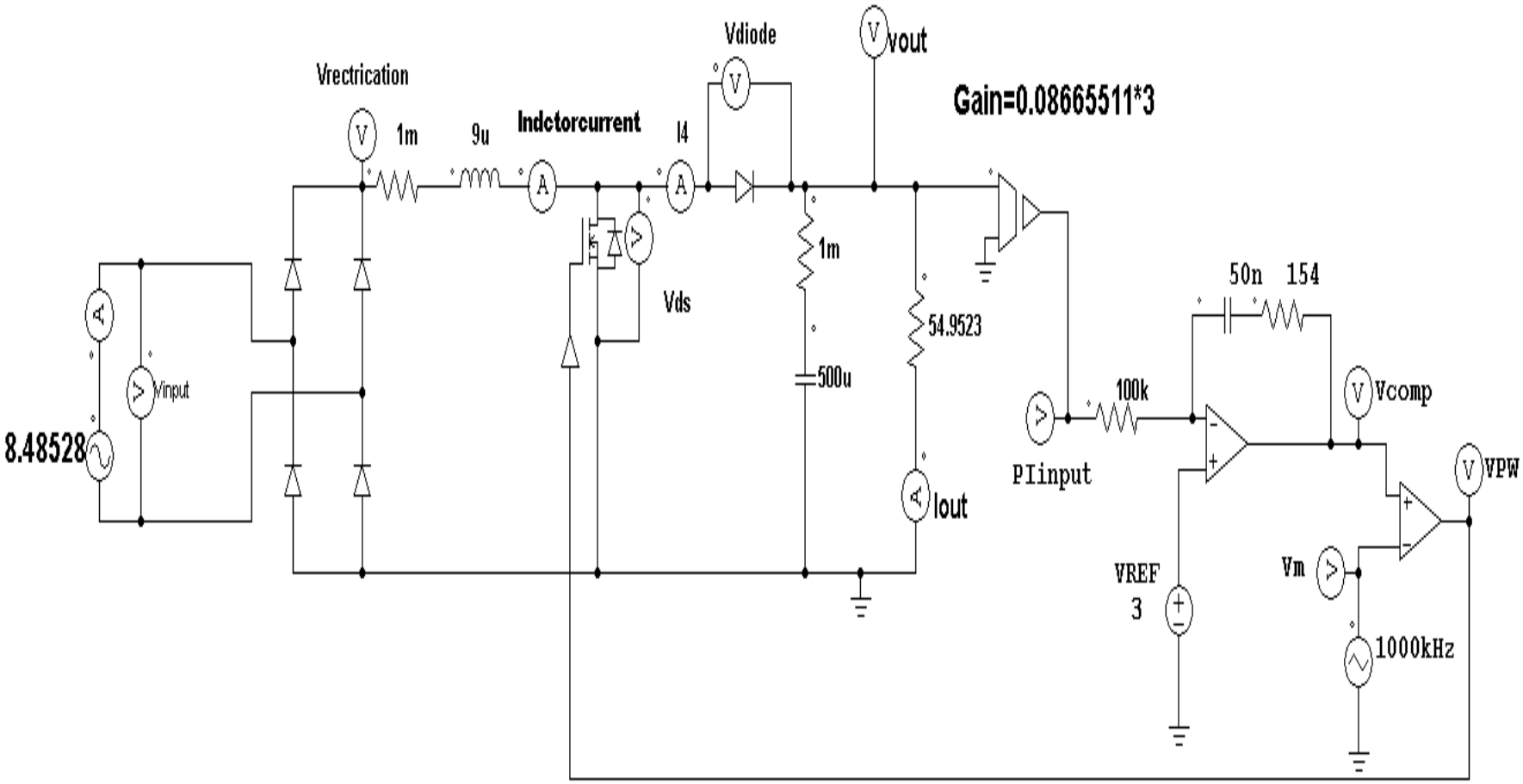


Fig 8.System with feedback

❖ Design of Operation Amplifier

- **An operational amplifier**, or op-amp, is a differential amplifier with very high differential-mode gain, very high input impedances, and a low output impedance (Ideal OpAmp).

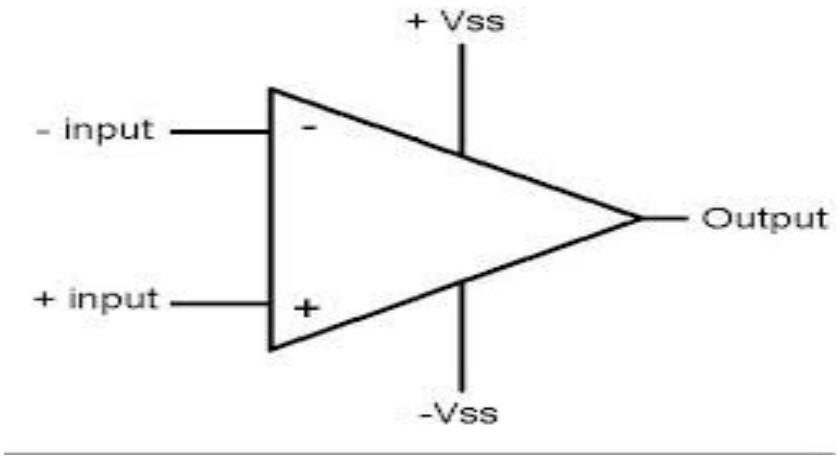


Fig 15. Symbol of Operational Amplifier

❖ Design of Operational Amplifier

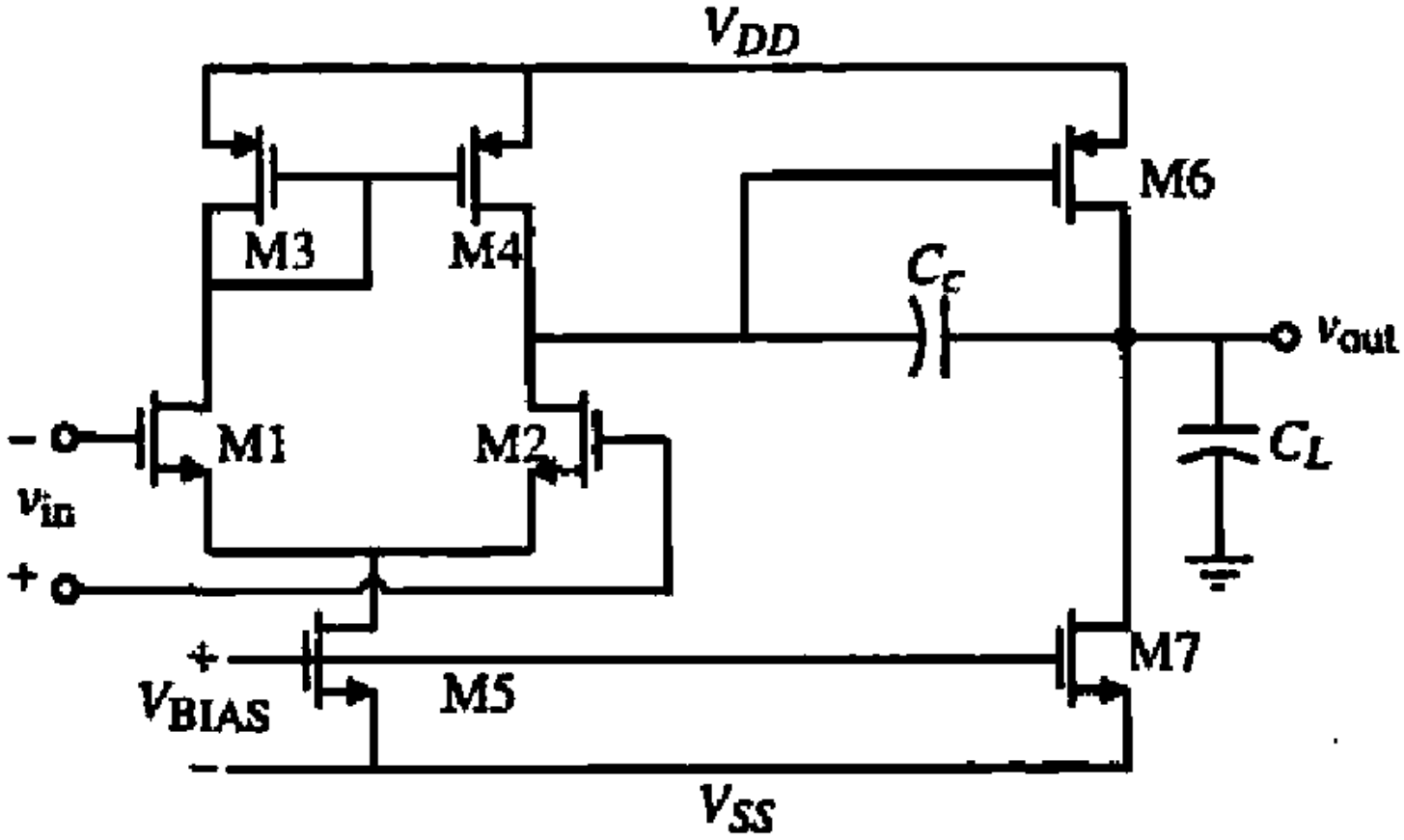


Fig 16. Operational Amplifier

❖ Design of Current Mirror

- **A current mirror** is a circuit designed to copy a **current** through one **active device** by controlling the current in another **active device** of a circuit , by changing in the ratio of the width and length of the MOSFET , according to the equation :

$$ID = \frac{\mu Cox}{2} \frac{W}{L} (Vgs - Vth)^2$$

❖ Current Mirror

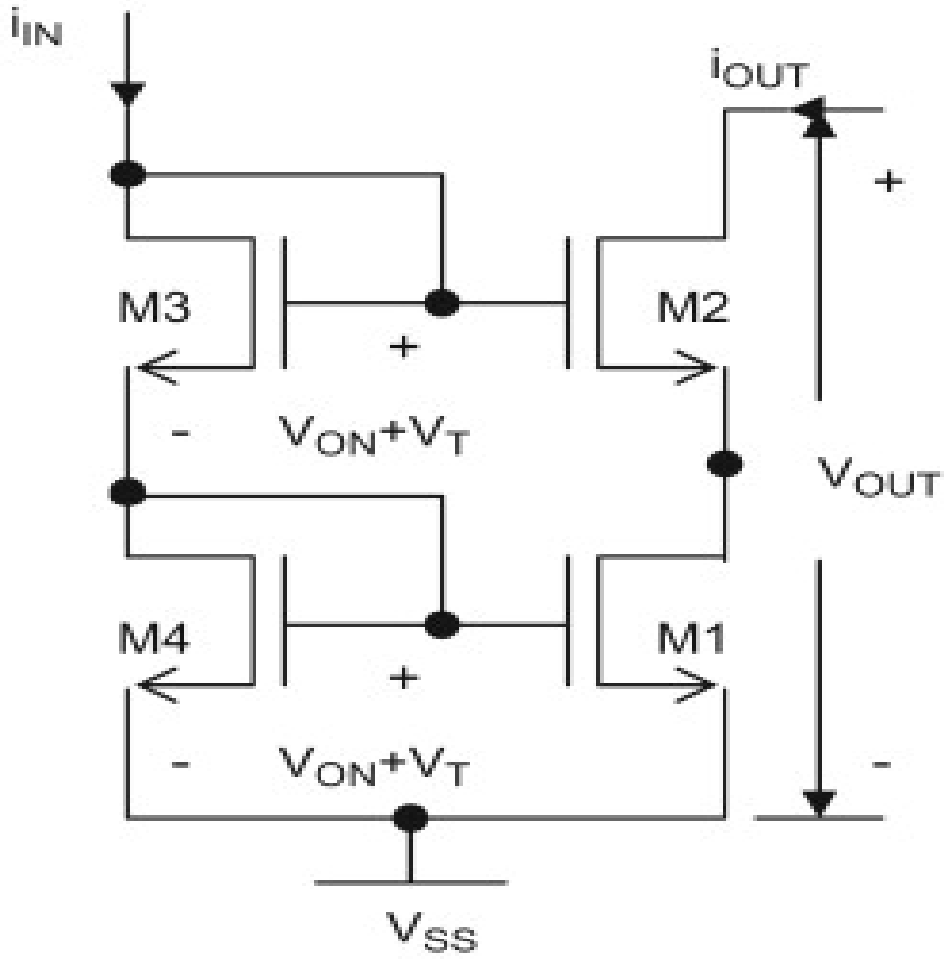
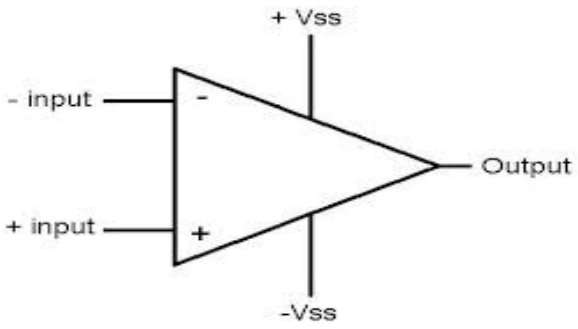


Fig 17. Current Mirror

❖ Design of Differential Amplifier

- **A differential amplifier** is a type of electronic amplifier that amplifies the difference between two voltages .



- **Vout = Ad (Vin_+ - Vin_-)** For ideal differential amplifier.
- Where **Vin_+** and **Vin_-** are the input voltages and **Ad** is the differential gain.

❖ Differential amplifier

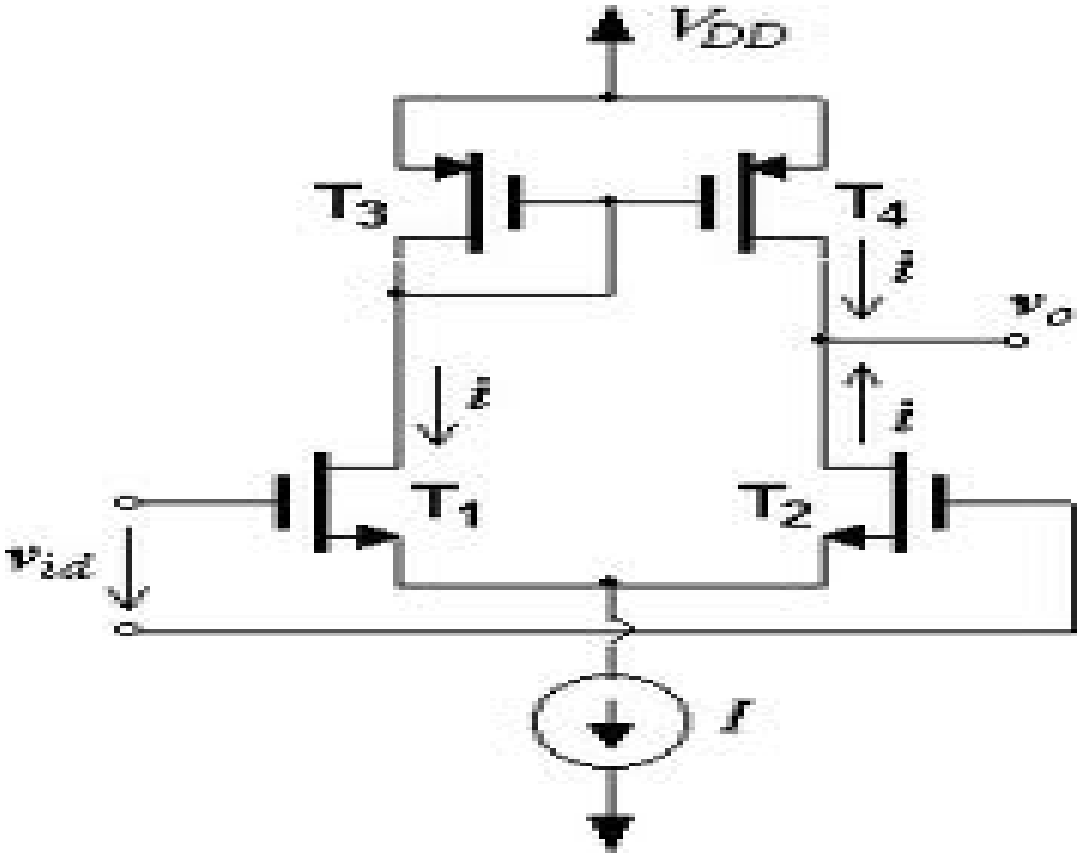
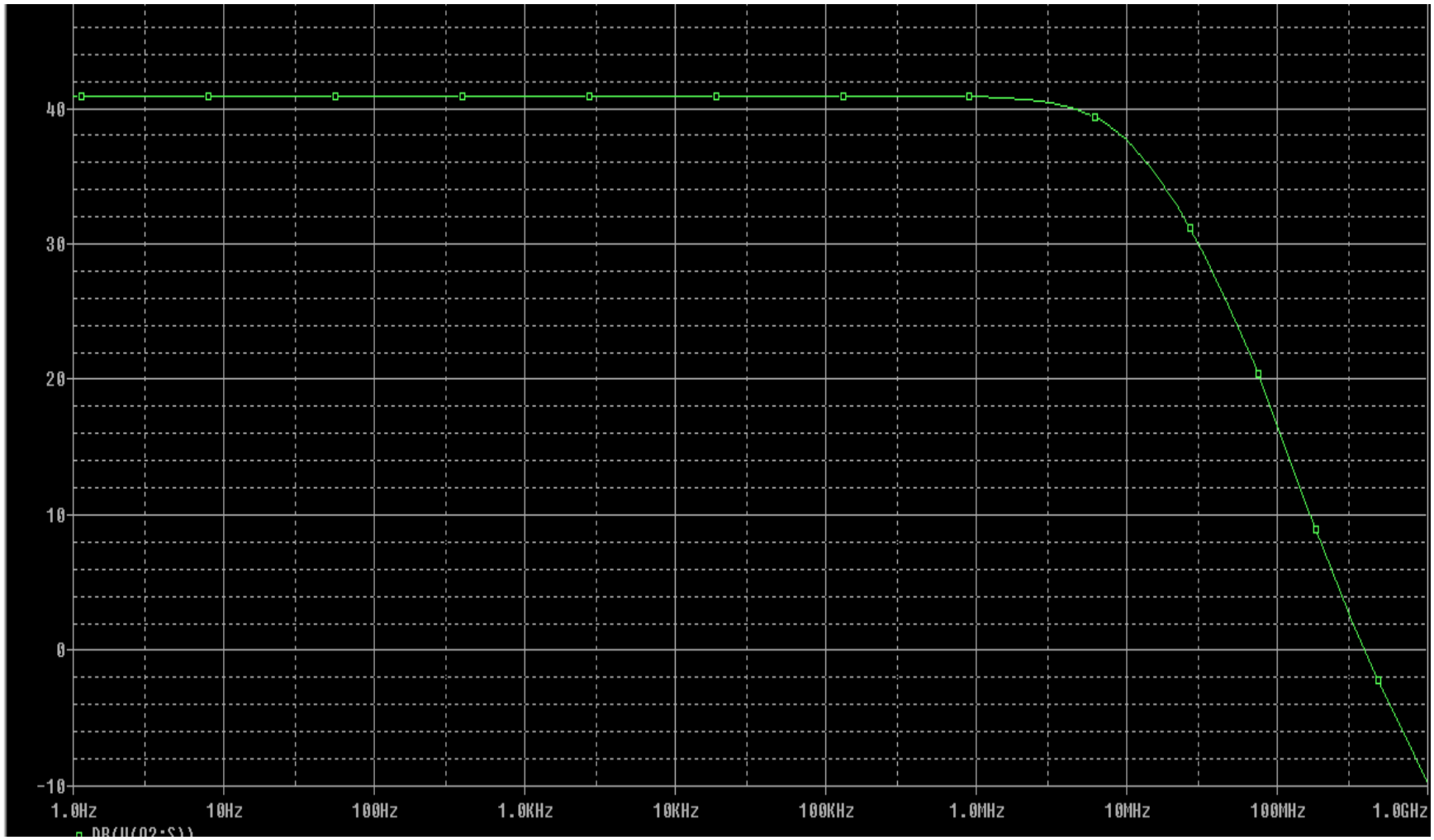


Fig 18. Differential Amplifier

❖ Test of Gain



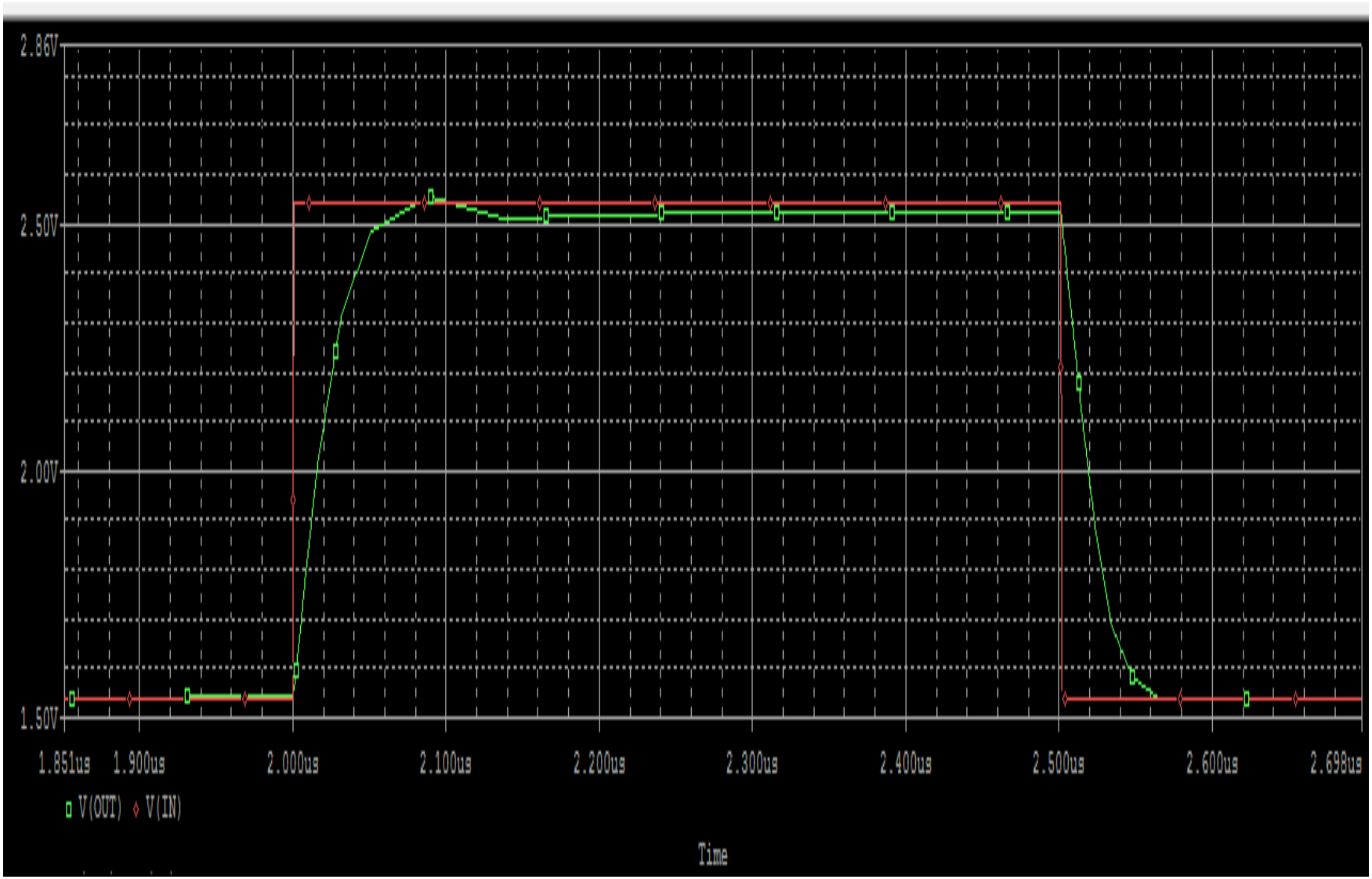
Gain

Frequency

❖ Slew Rate of Differential Amplifier

- **Slew rate** is defined as the maximum rate of change of output voltage per unit of time and is expressed as volt per micro second.
- $\mathbf{SR} = \frac{dv}{dt}$ **(Vμs)**

❖ Slew Rate Test



Input Voltage & Output Voltage

Time

❖ Design of Operational Amplifier

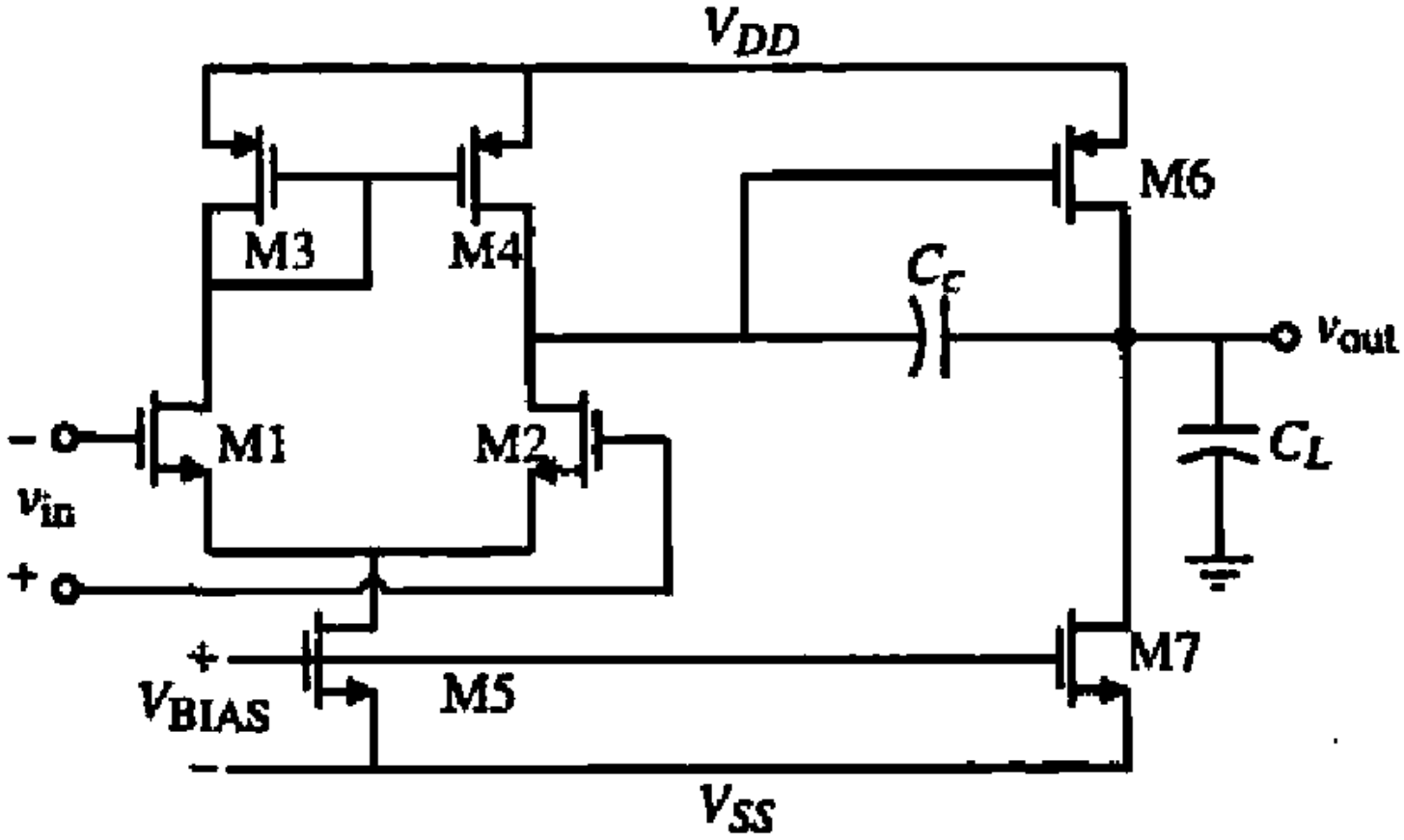
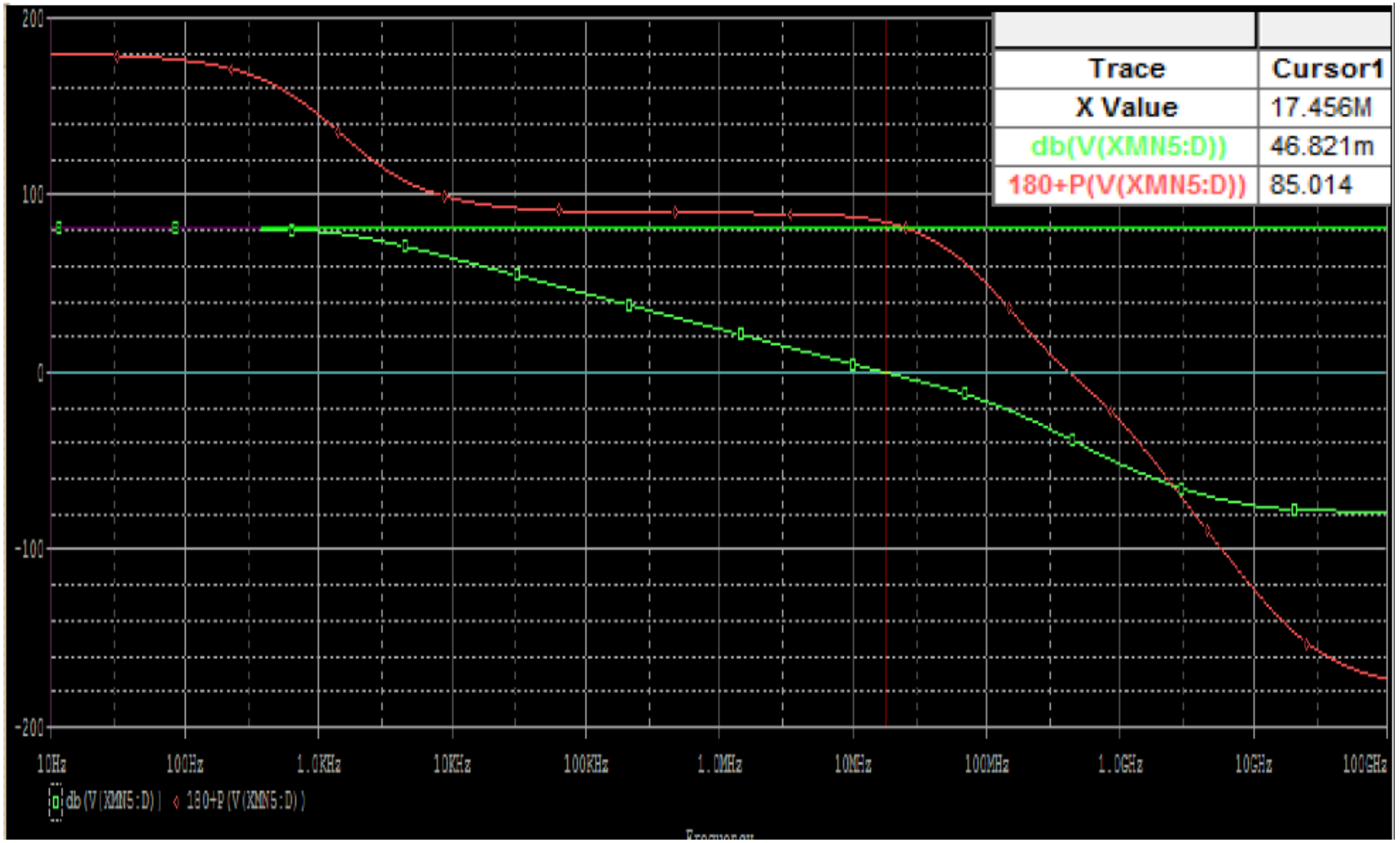


Fig 16. Operational Amplifier

❖Test of Gain and Phase

Phase

Gain



Frequency

❖ Ramp circuit

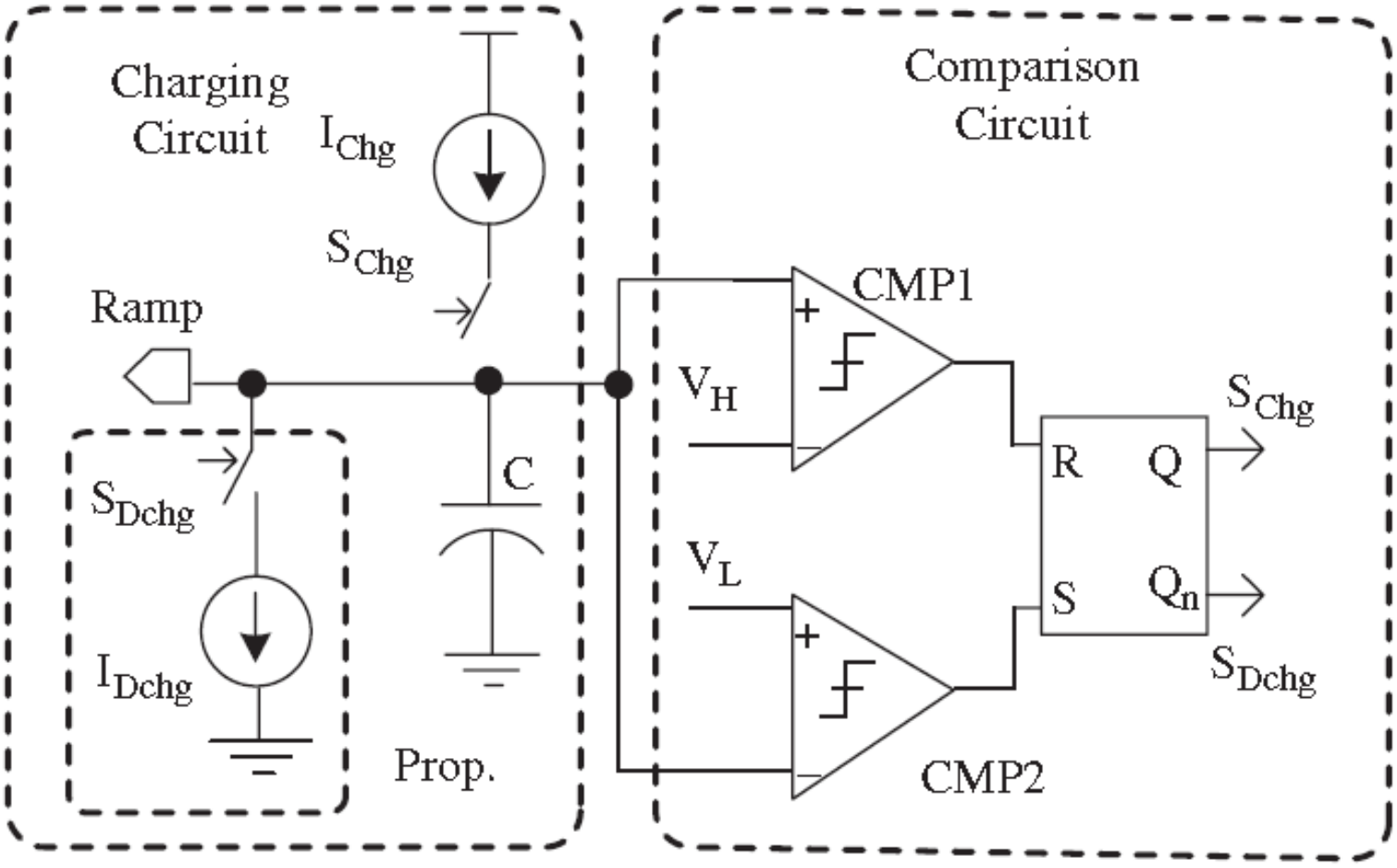


Fig 19.Ramp circuit

❖ Ramp oscillator

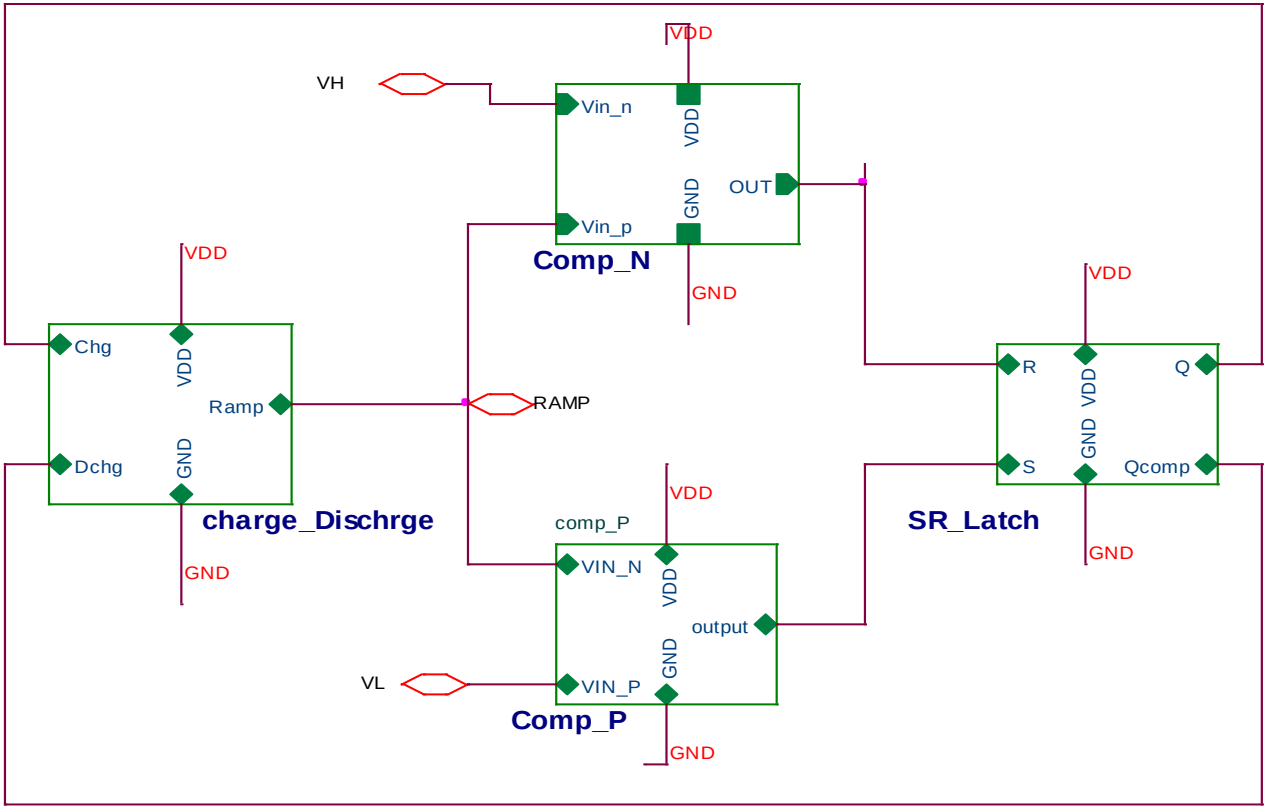
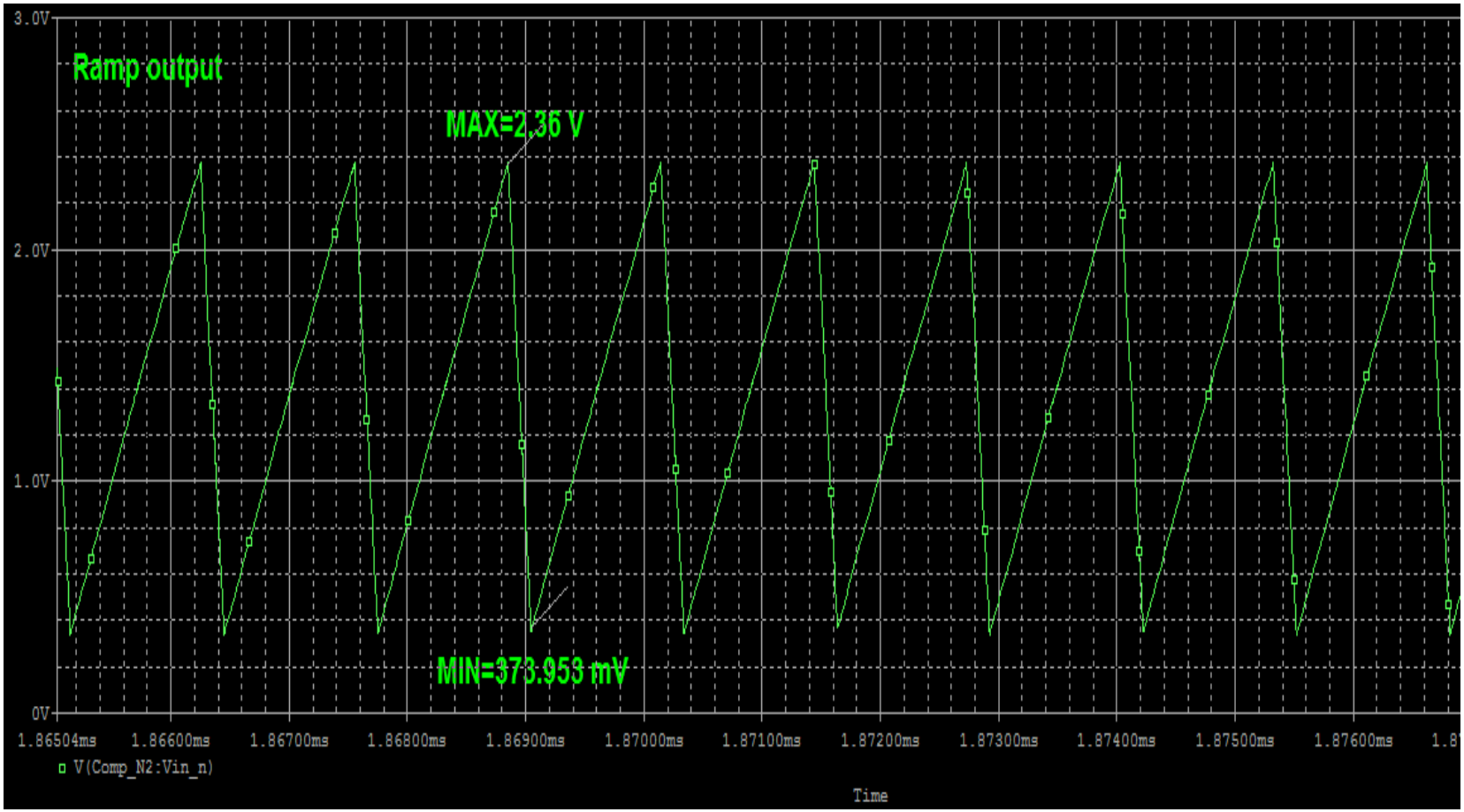
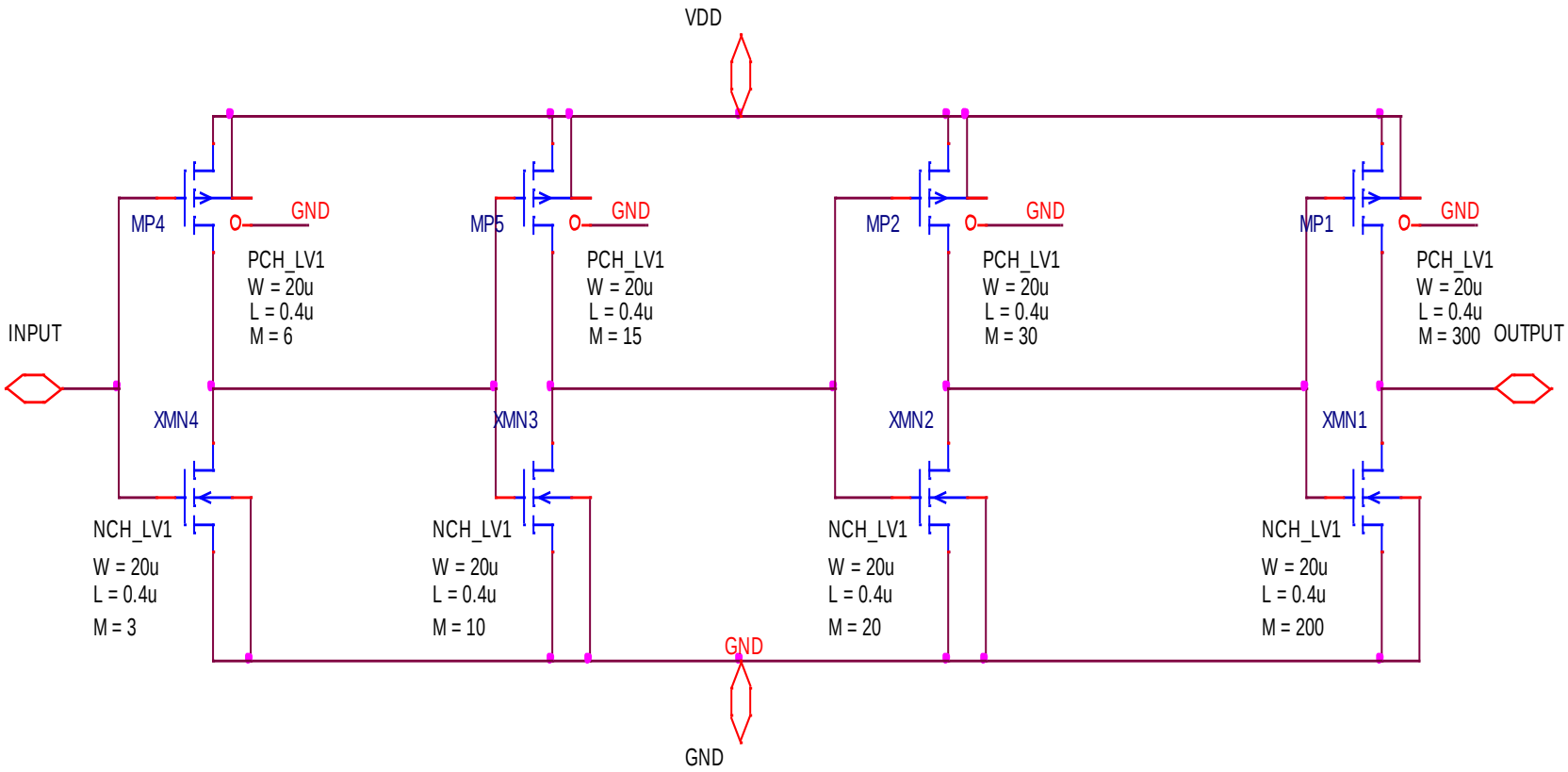


Fig 20 . Ramp Oscillator

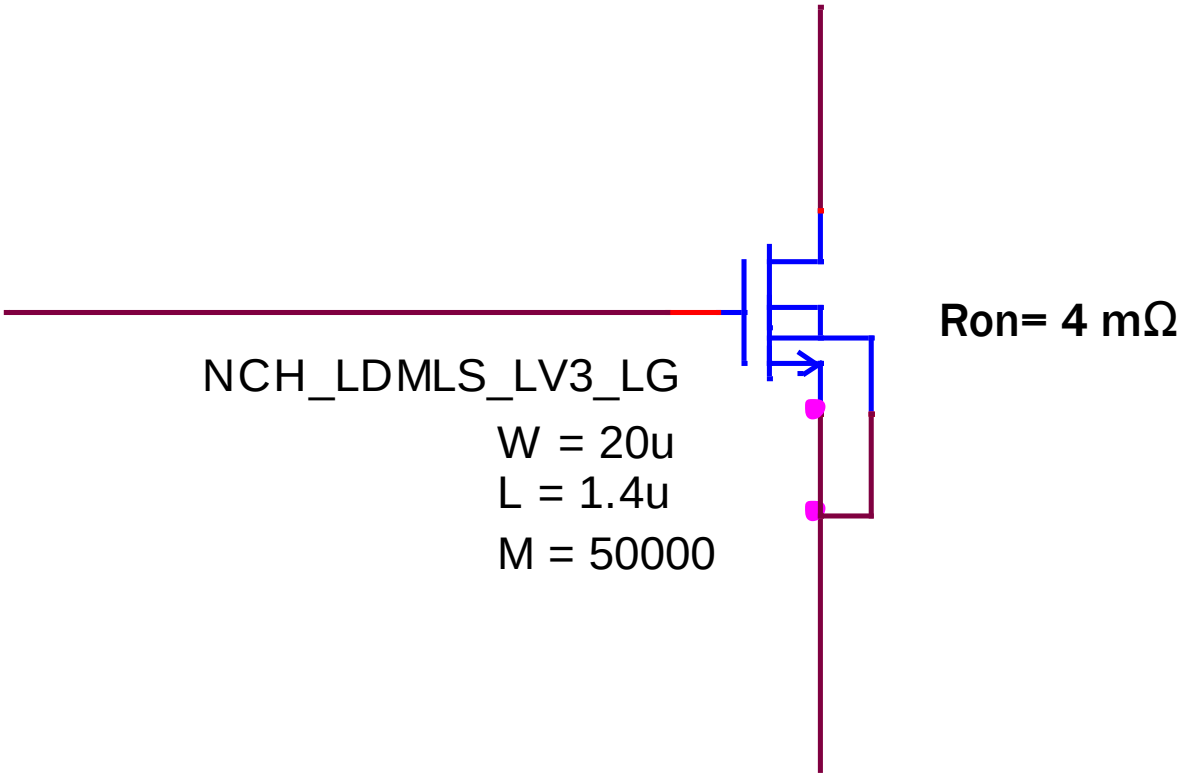
❖ Ramp output


Ramp output
MAX=2.36 V
MIN=373.953 mV
3.0V
2.0V
1.0V
0V
1.86504ms
1.86600ms
1.86700ms
1.86800ms
1.86900ms
1.87000ms
1.87100ms
1.87200ms
1.87300ms
1.87400ms
1.87500ms
1.87600ms
V(Comp_N2:Vin_n)
Time

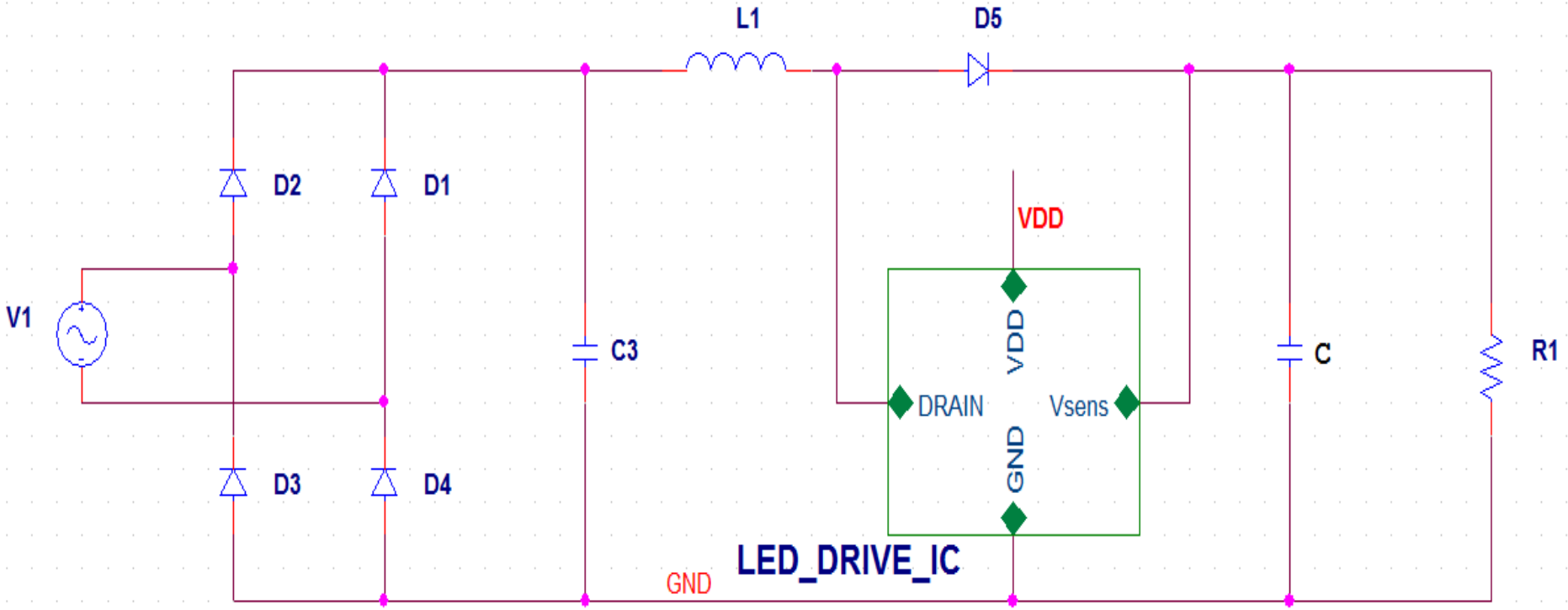
❖ Gate Driver


VDD
INPUT
OUTPUT
GND
GND
MP4
MP5
MP2
MP1
PCH_LV1
W = 20u
L = 0.4u
M = 6
PCH_LV1
W = 20u
L = 0.4u
M = 15
PCH_LV1
W = 20u
L = 0.4u
M = 30
PCH_LV1
W = 20u
L = 0.4u
M = 300
XMN4
XMN3
XMN2
XMN1
NCH_LV1
W = 20u
L = 0.4u
M = 3
NCH_LV1
W = 20u
L = 0.4u
M = 10
NCH_LV1
W = 20u
L = 0.4u
M = 20
NCH_LV1
W = 20u
L = 0.4u
M = 200

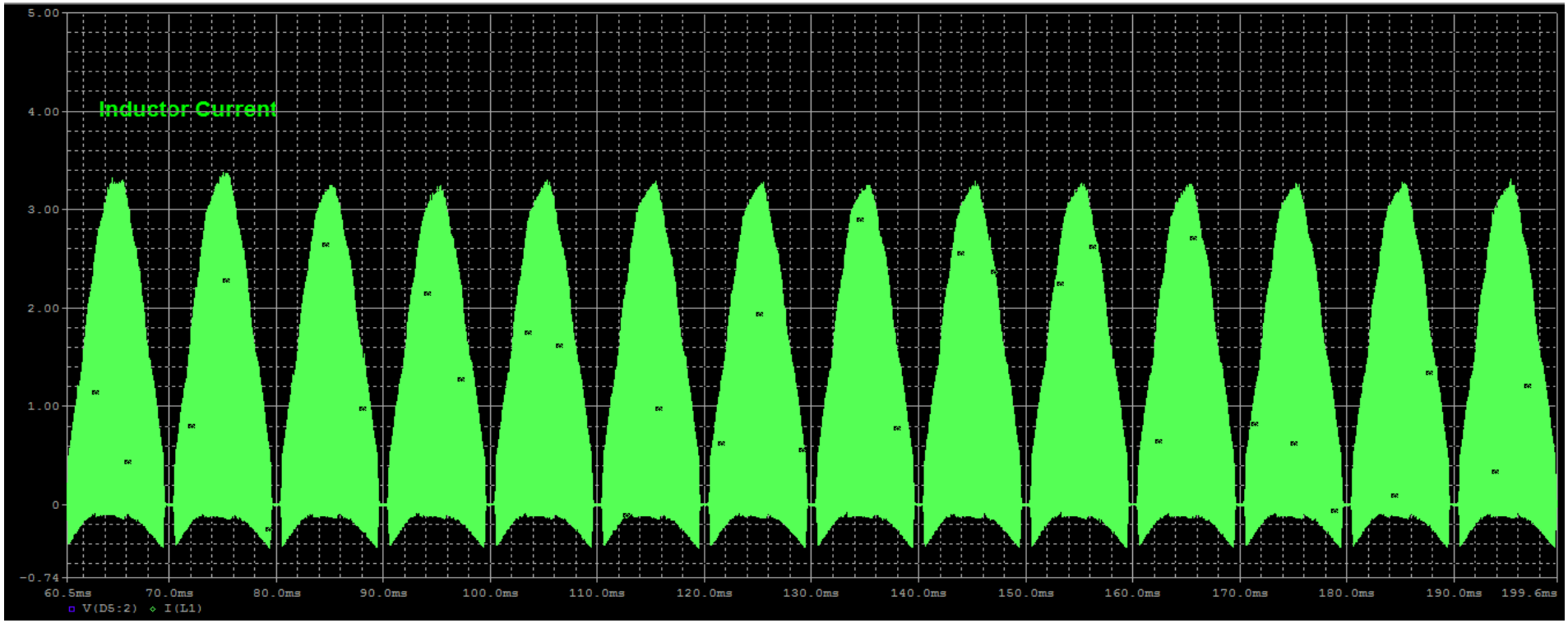
❖ Power FET Design



TOP Level System

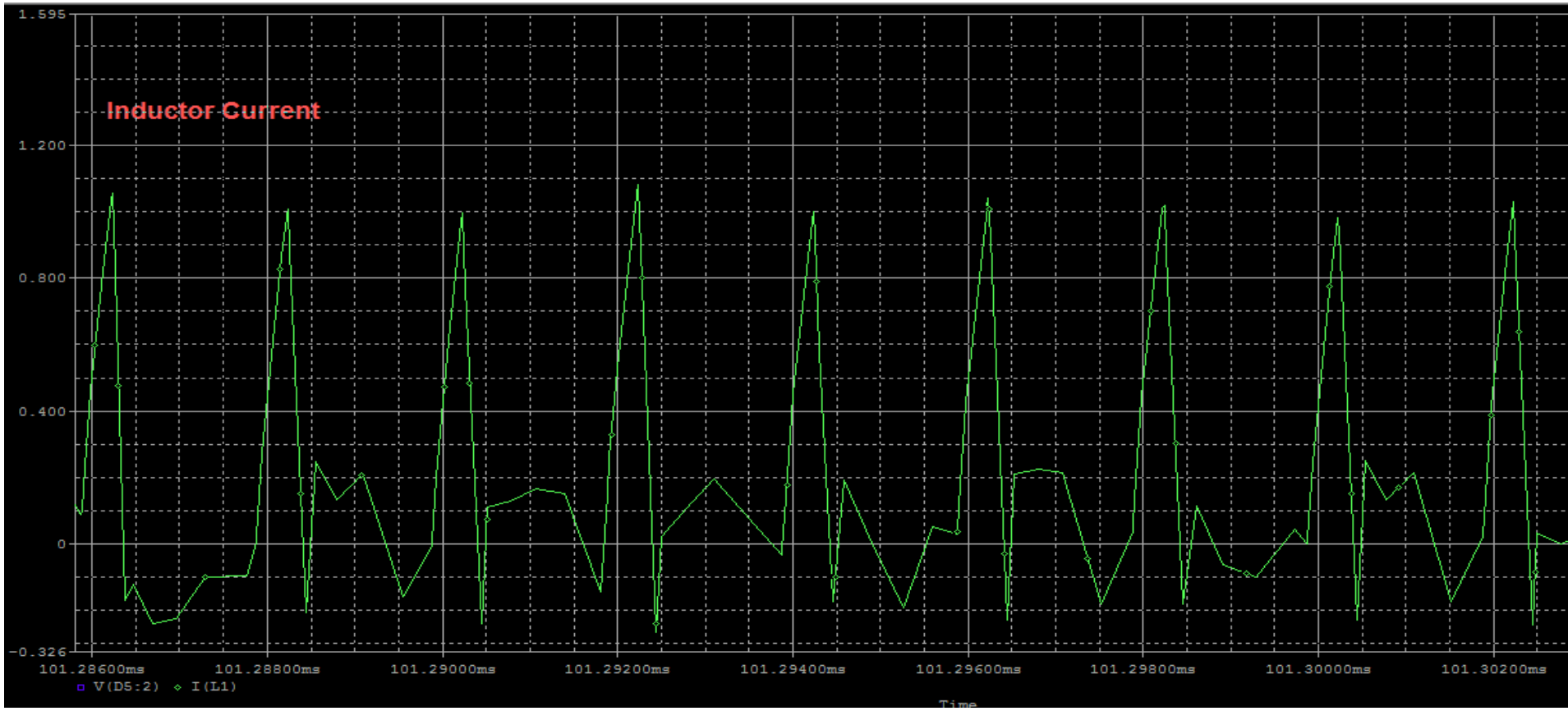


Top Level Simulation Result



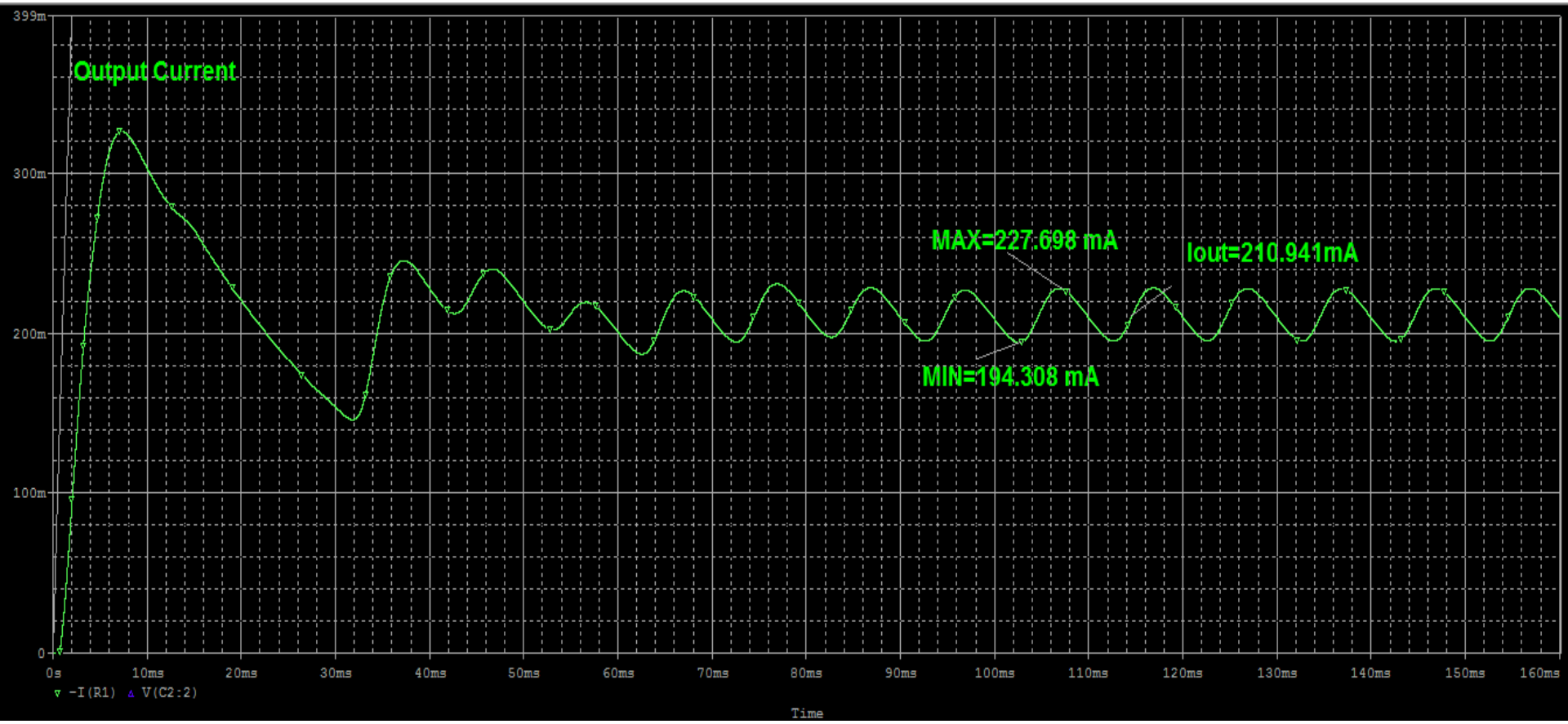
Inductor current

Top Level Simulation Result



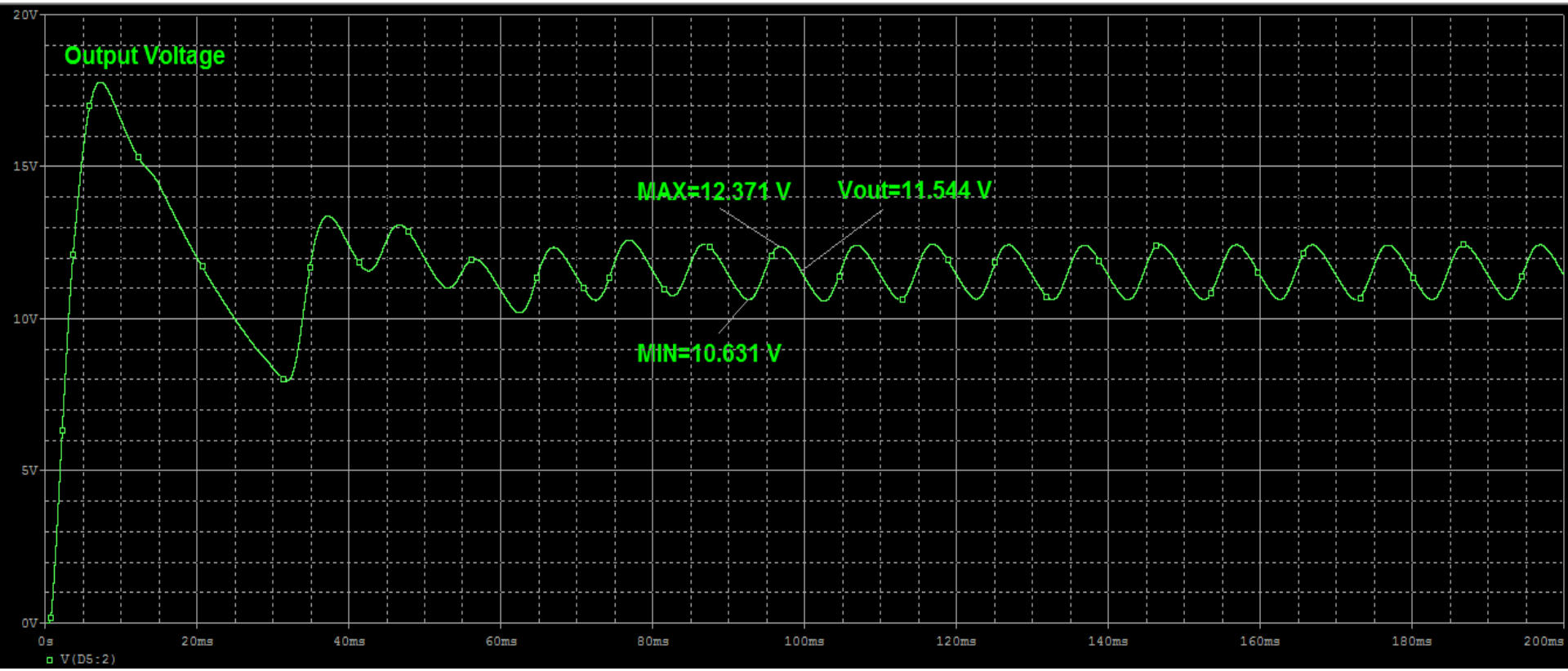
Inductor current

Top Level Simulation Result



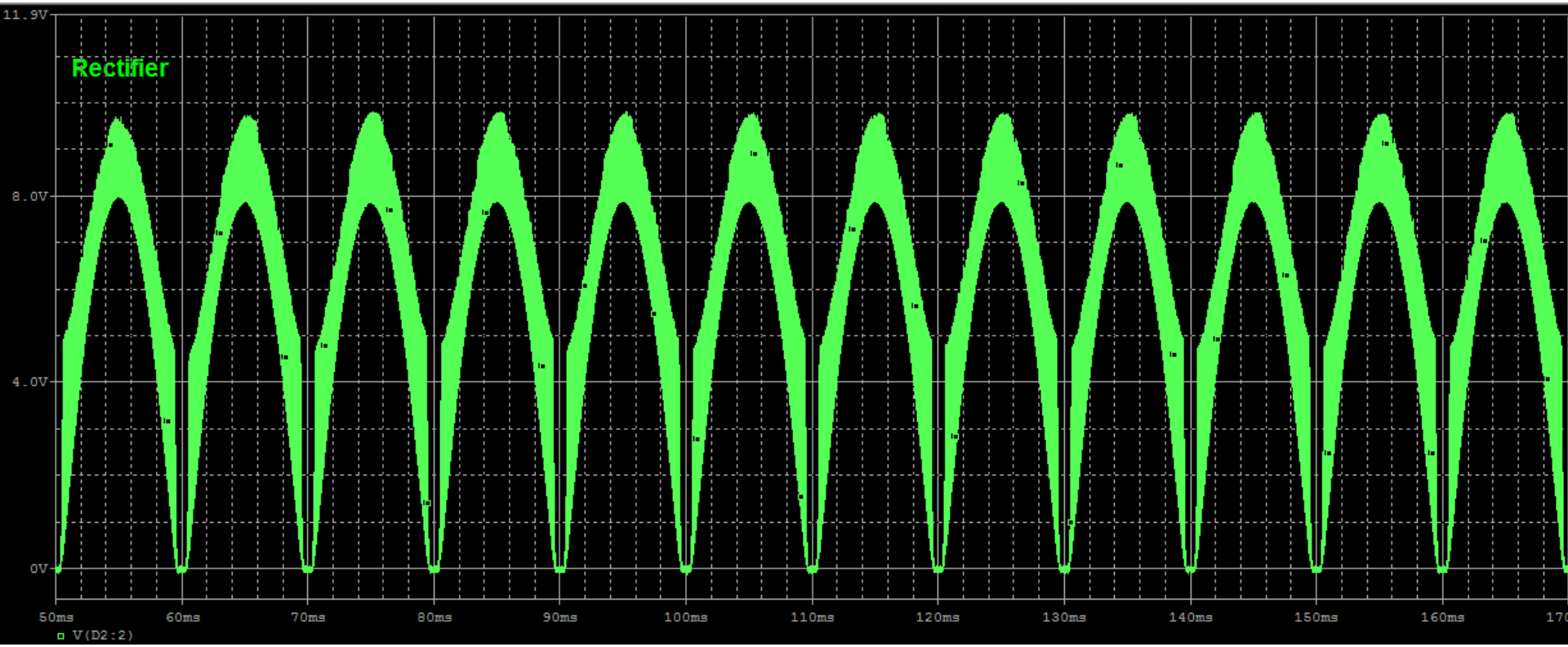
Output current

Top Level Simulation Result



Output Voltage

Top Level Simulation Result

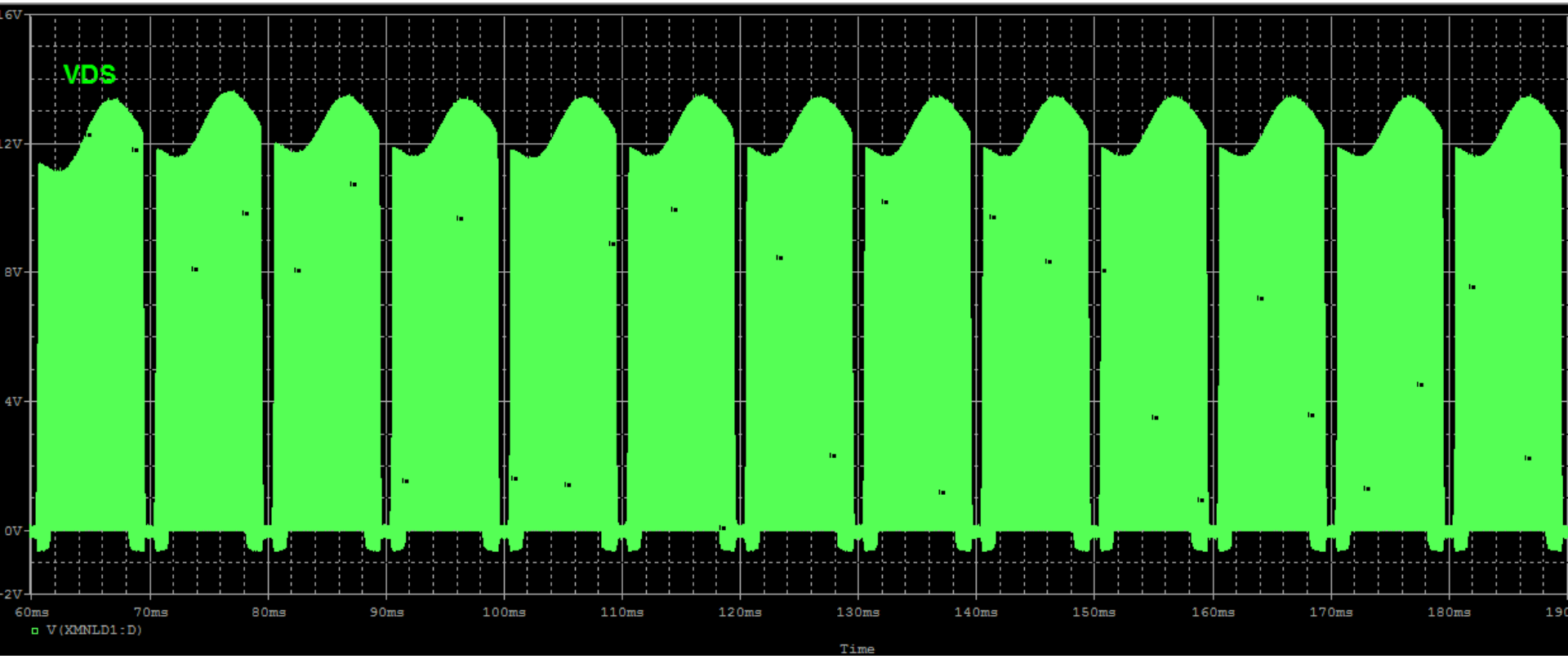


Rectifier Output

Top Level Simulation Result

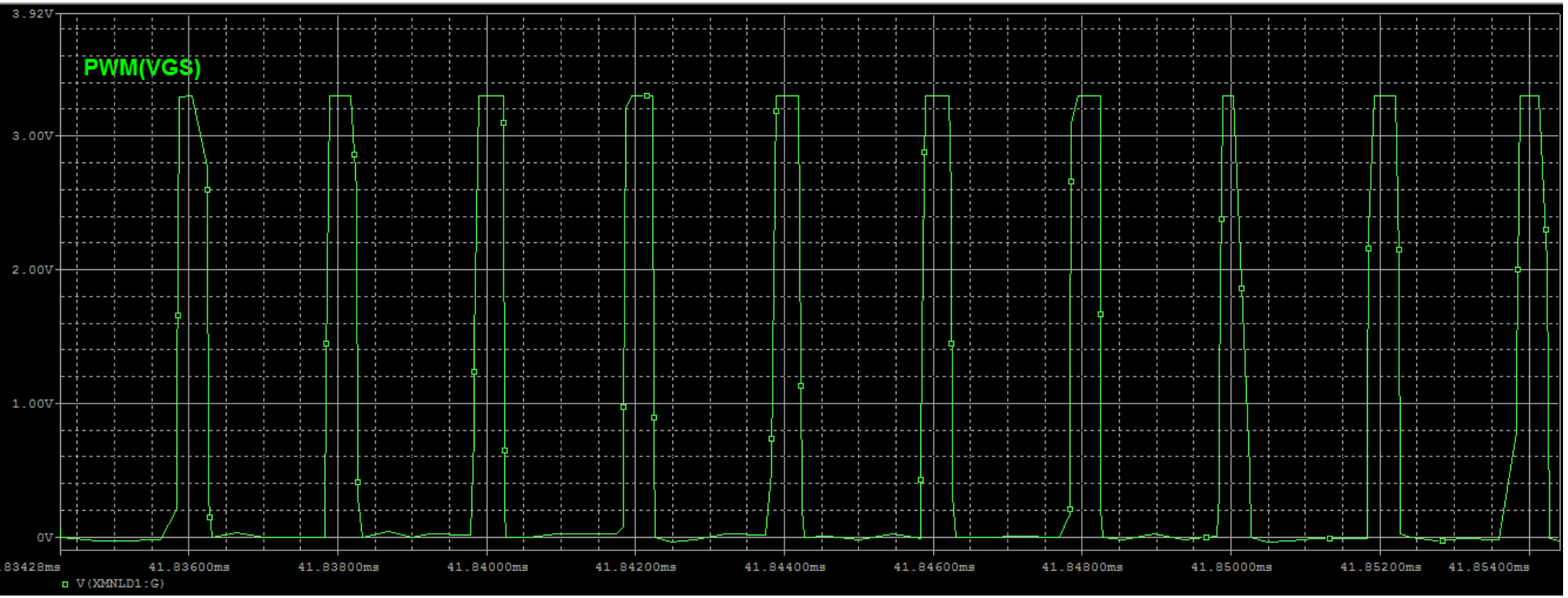
PI output

Top Level Simulation Result



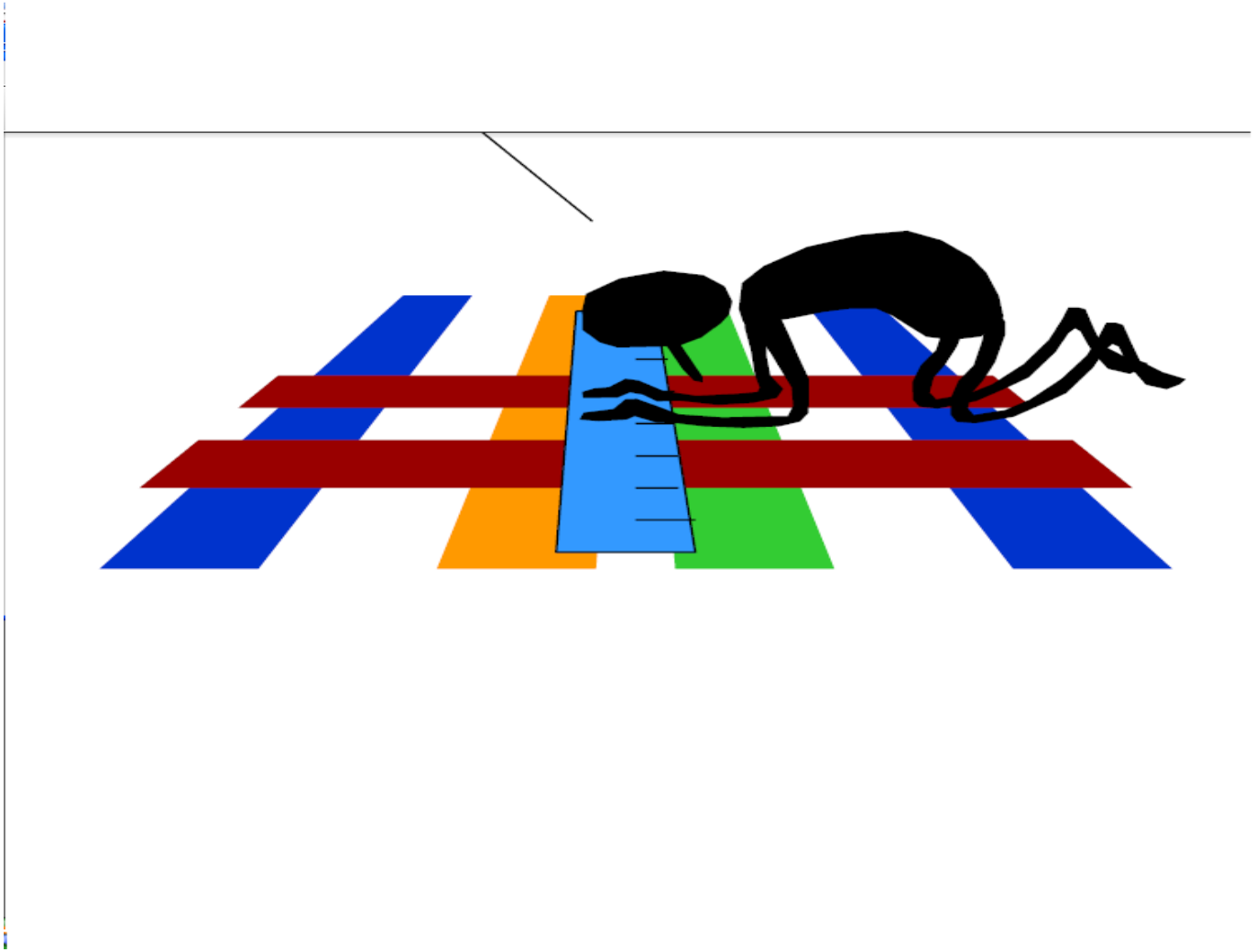
V drain Source

Top Level Simulation Result



PWM (Gate drive output)

❖ IC Layout



❖ IC Layout

- Converts a circuit description into a geometric description to be fabricated
- **Integrated circuits**: many transistors on one chip.
  - *Very Large Scale Integration* (VLSI): very many
- ***Metal Oxide Semiconductor* (MOS) transistor**
  - cheap, low-power transistors
  - Complementary: mixture of n- and p-type leads to less power
- **Basic Layout Component :**

1. CMOS Transistors
2. Capacitors
3. Resistors

n-channel Transistor

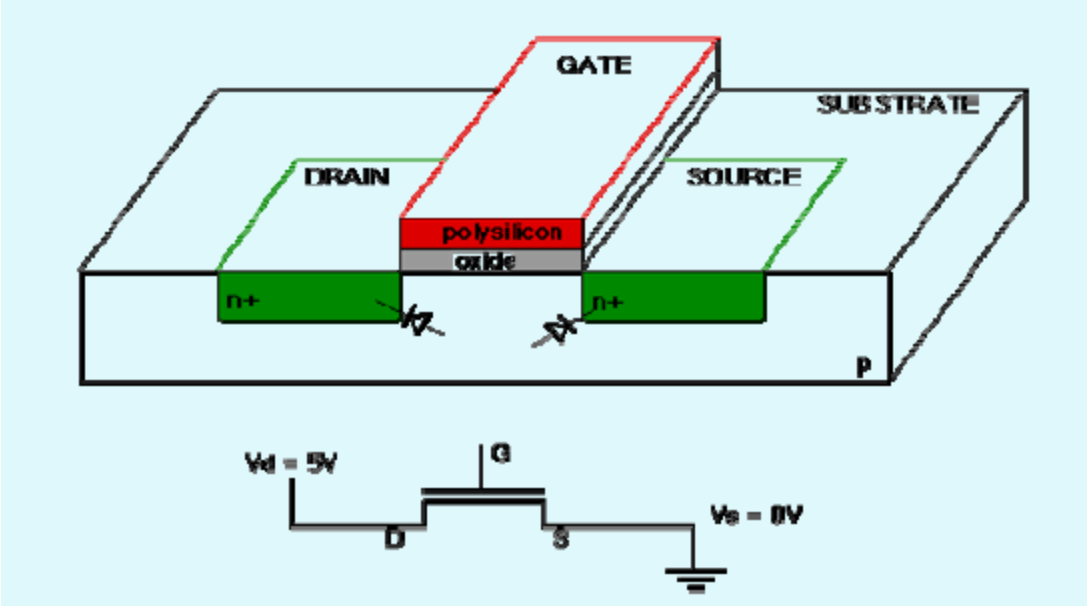


Fig 21. n-channel Transistor

- Four-Terminal device:

1. gate
2. source
3. drain
4. body

n-channel Transistor Layout

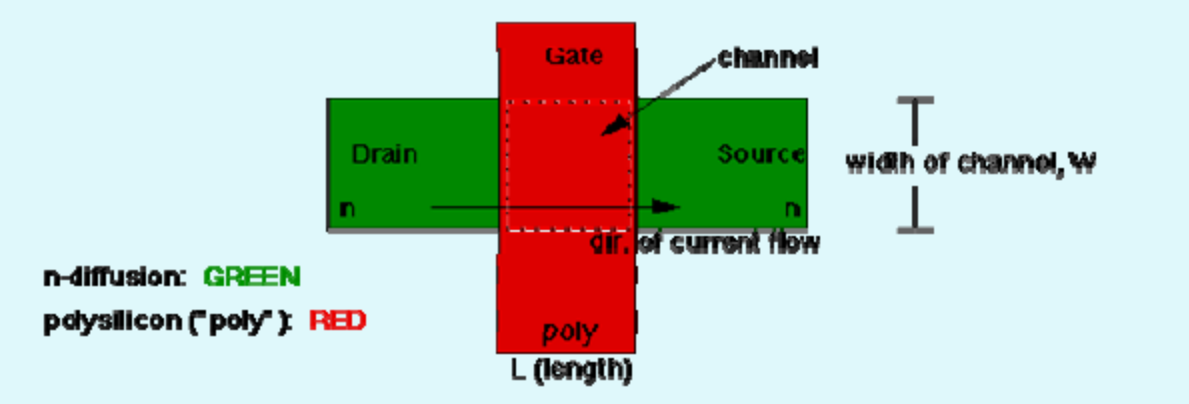


Fig 22. n-channel Transistor Layout

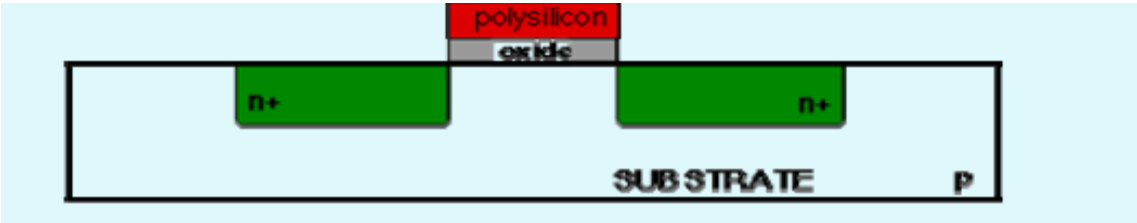


Fig 23. n-channel Transistor

p-channel MOS Transistor

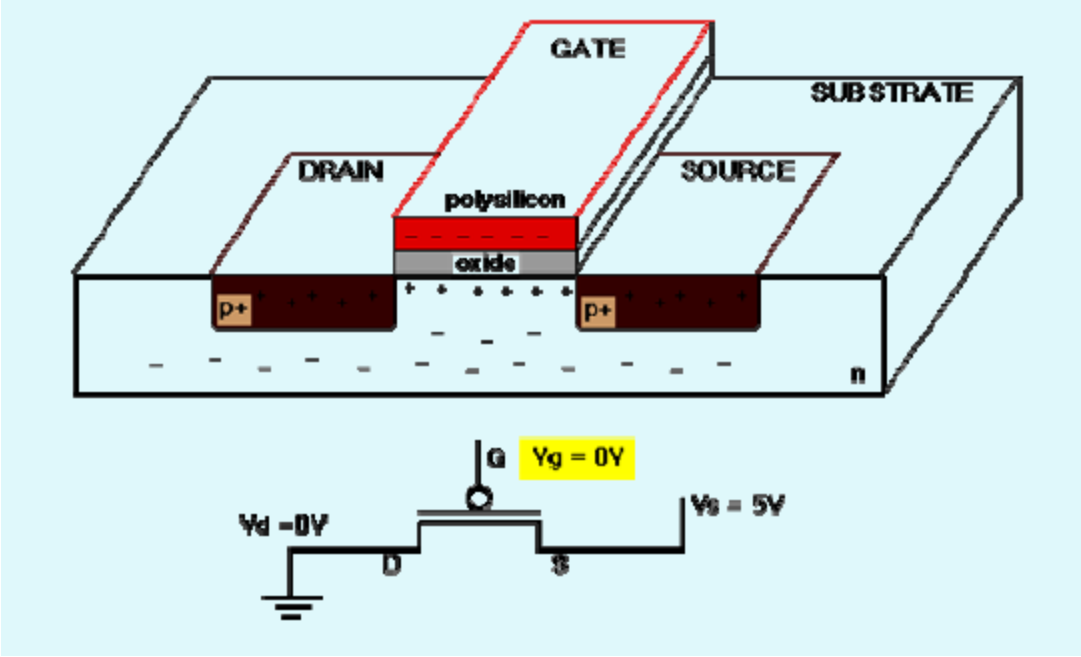


Fig 24. p-channel MOS Transistor

Fabrication Layers

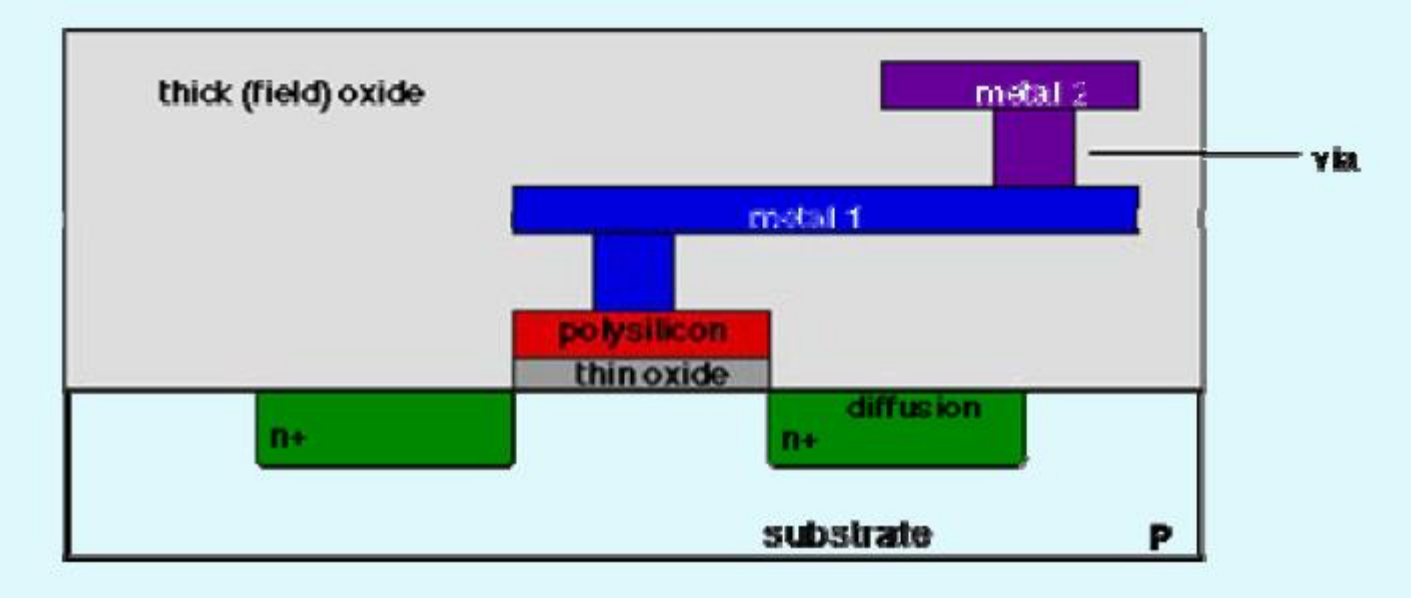


Fig 25. Fabrication Layers

MOS Transistor Behavior

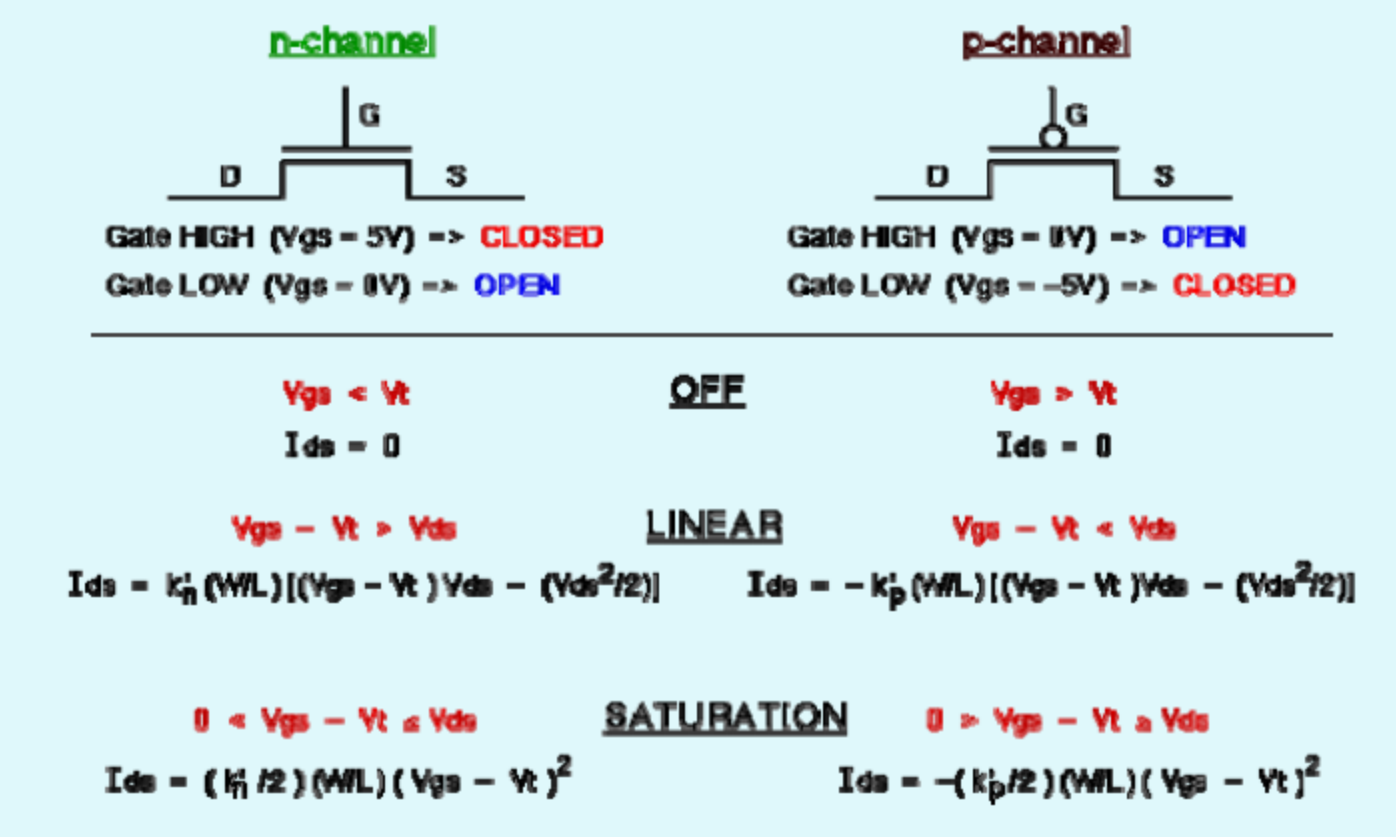


Fig . MOS Transistor Behavior

CMOS Transistor

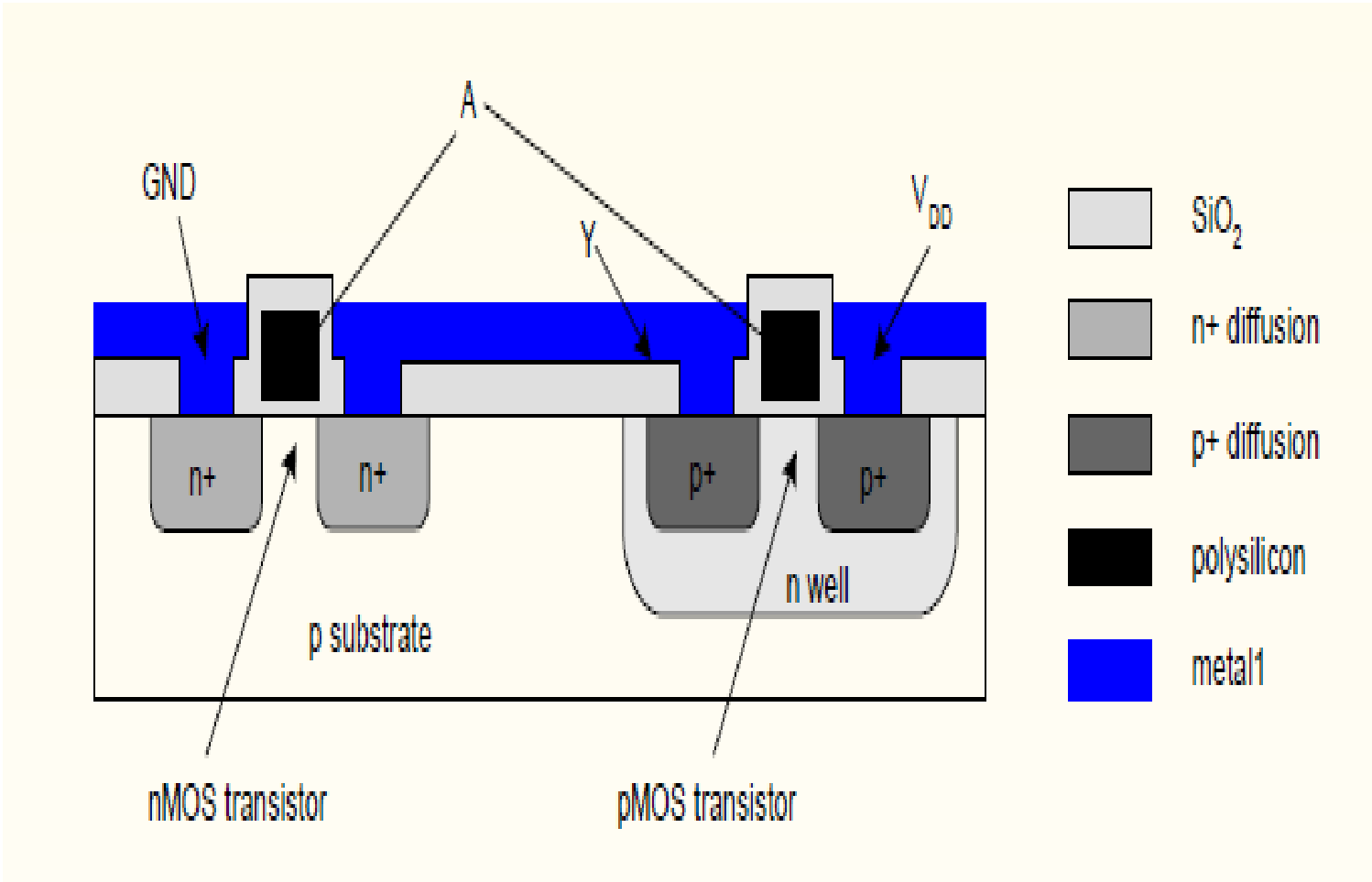


Fig 27. CMOS Transistor

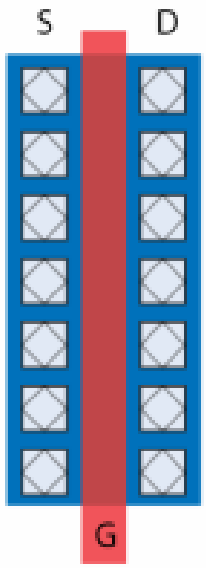
CMOS Transistors

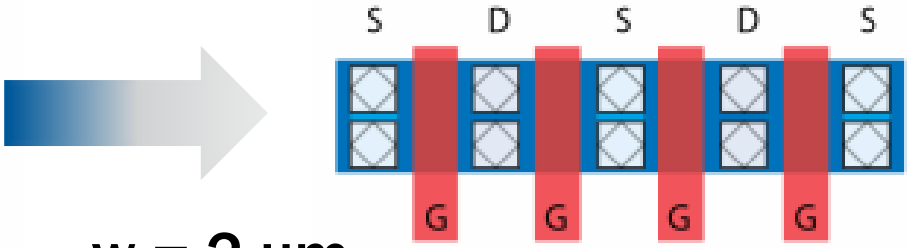
- Multi Fingers

w = 8 um

l = 0.5 um

nf = 1





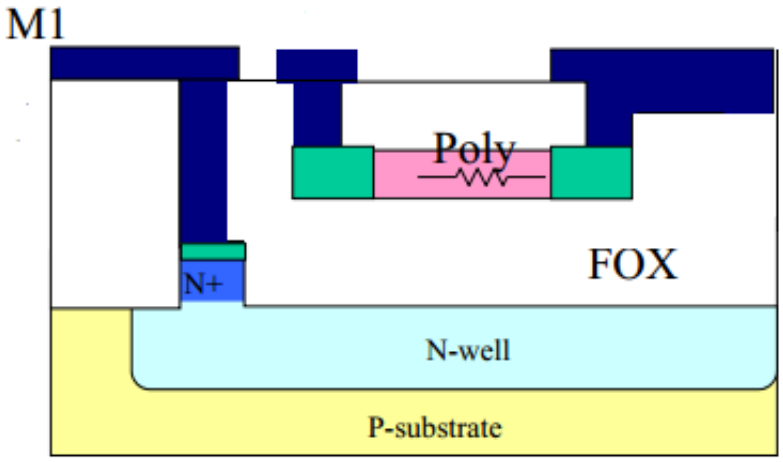
w = 2 um

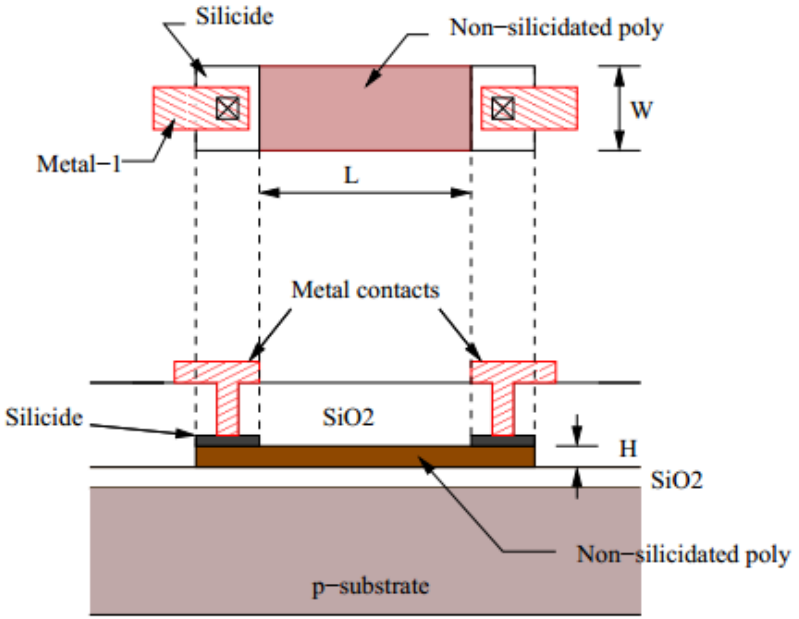
l = 0.5 um

nf = 4

Resistors

- **Poly Resistor Structure**





Resistors

- Resistance (Ω) = No. of squares * Sheet Res. (Ω /□)
- Parameters Affecting the Res. Value
  - Width
  - Length
  - Sheet resistance (Ω /□)
  - No. of fingers (Contacts)

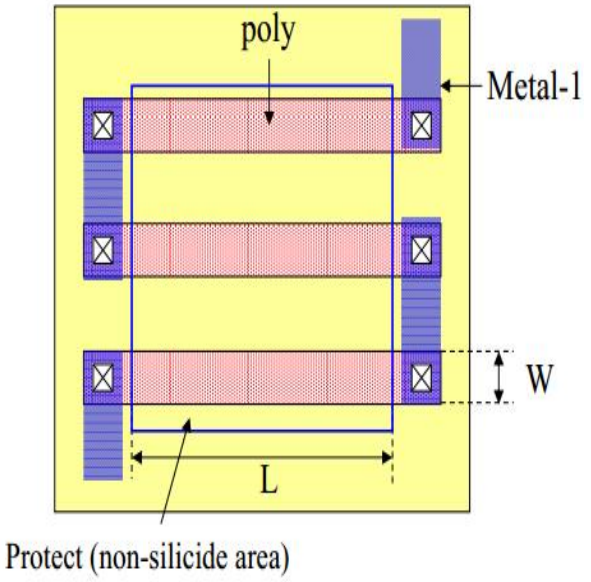


Fig 28. Resistor

Matching

- Process variations during fabrication may limit accuracy and desired performance of analog circuits
- Matching between components in layout is an important issue in many designs; like current mirrors and diff. pairs

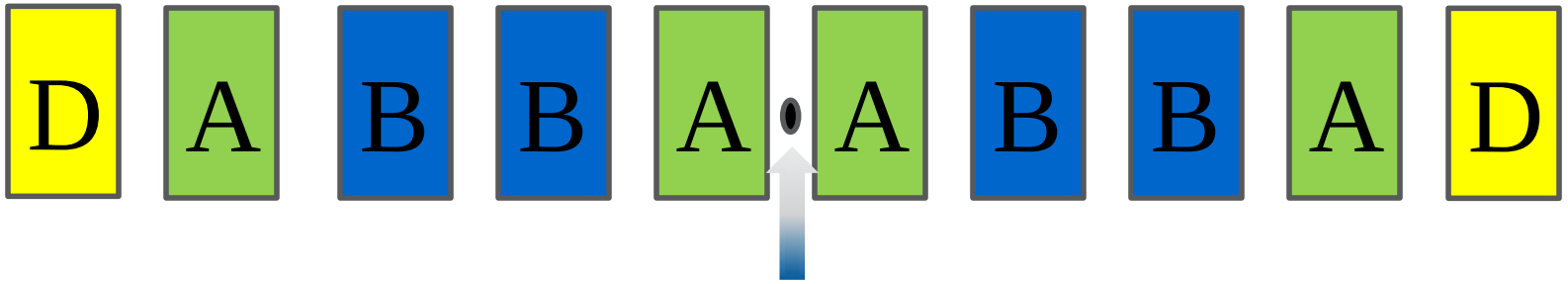
❑**Matching Techniques:**

- Common Centroid
- Inter-Digitization

Example : we match two components A(A1-A4) and B(B1-B4) and A,B are any component

Common Centroid

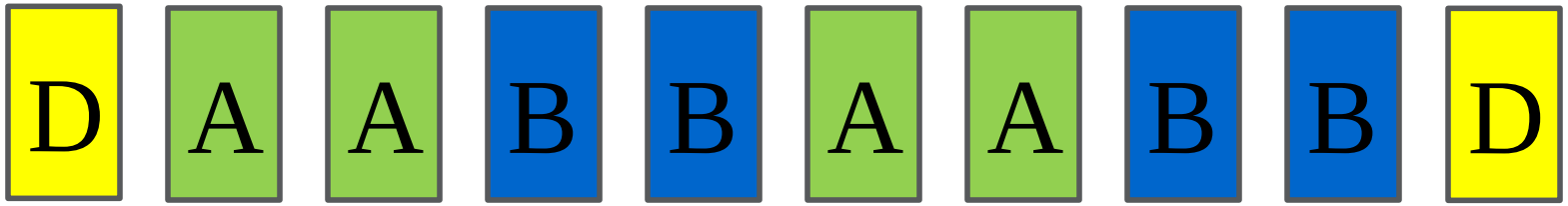
- Common centroid Technique: Placing components such that both components have same centroid.
- Both A and B have common center



- This Technique is used in Current Mirror

Inter-Digitization

- Inter-digitization Technique: Placing alternate components



This Teqnique is used in Differential Amplifier

the three basic DRC checks

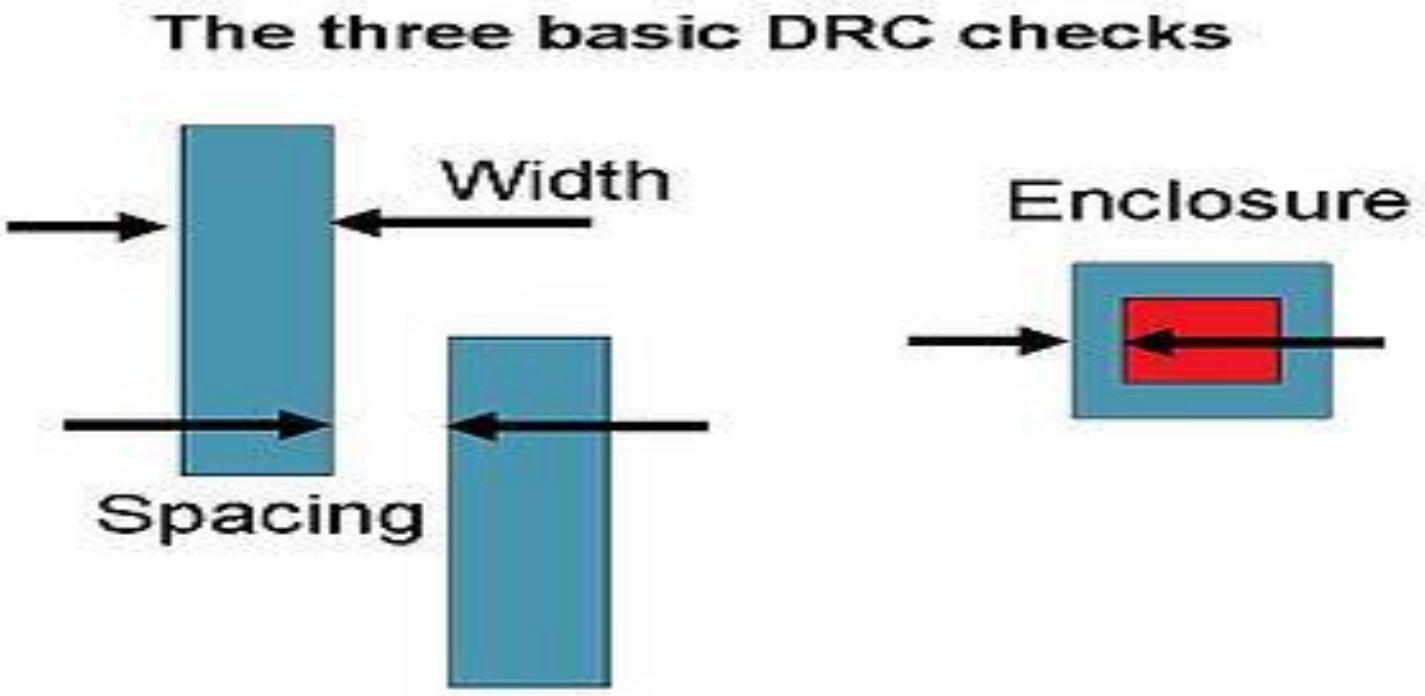


Fig 29. DRC check

Layout of IC

Layout of :

- NMOS & PMOS
- Capacitor (DN-well ,SP-well)
- Resistor
- Low Pass Filter
- Inverter
- Current Mirror
- Differential Amplifier
- Operational Amplifier

❑ PMOS

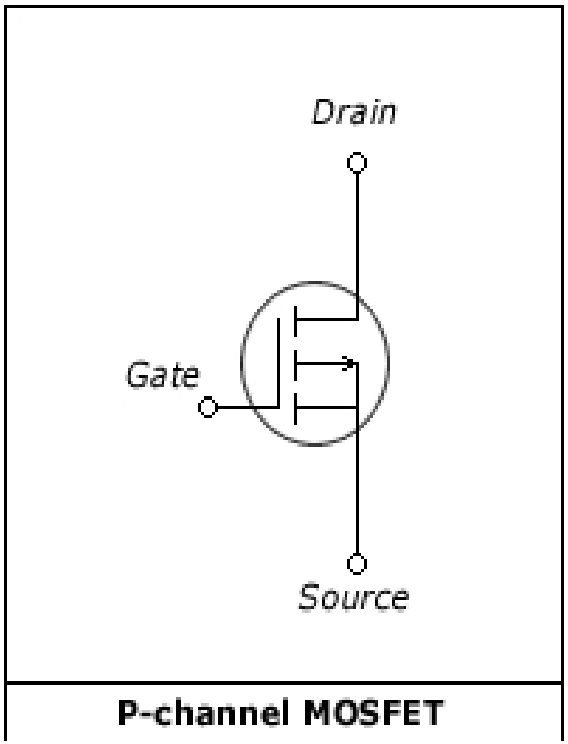


Fig 20. p channel MOSFET

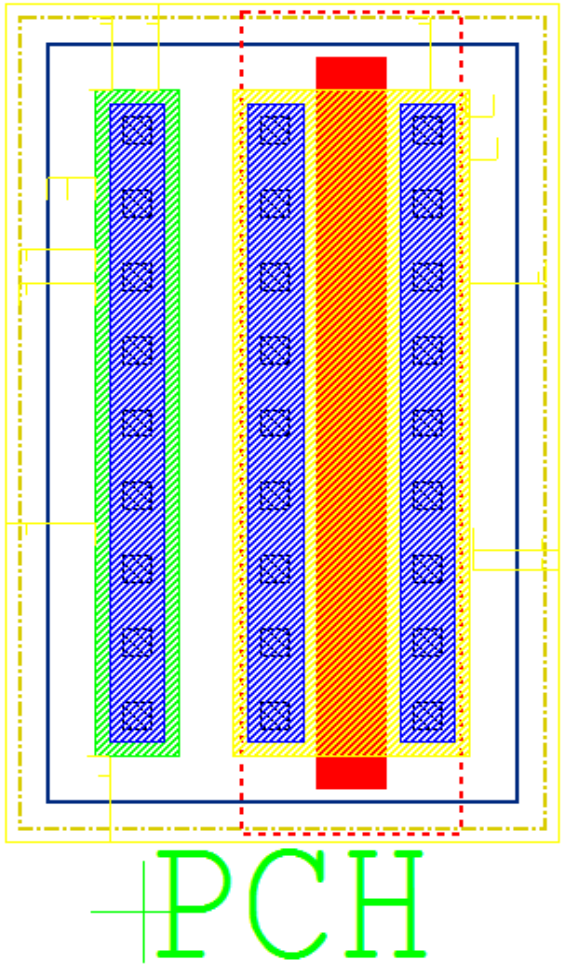


Fig 21.Layout of P channel MOSFET

❑ NMOS

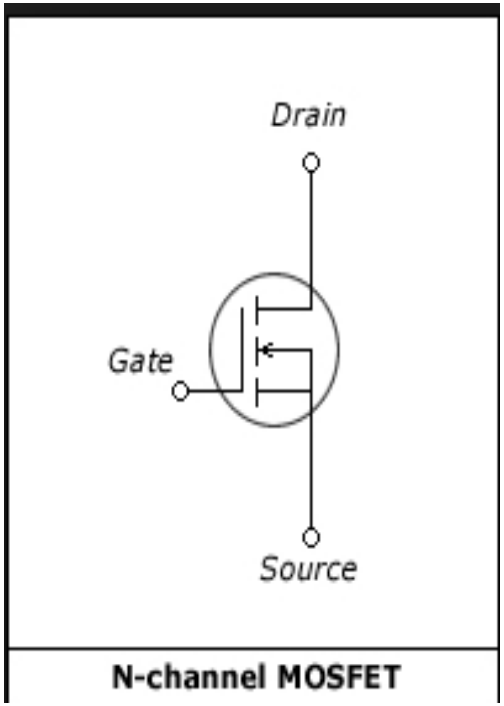


Fig 22. N channel MOSFET

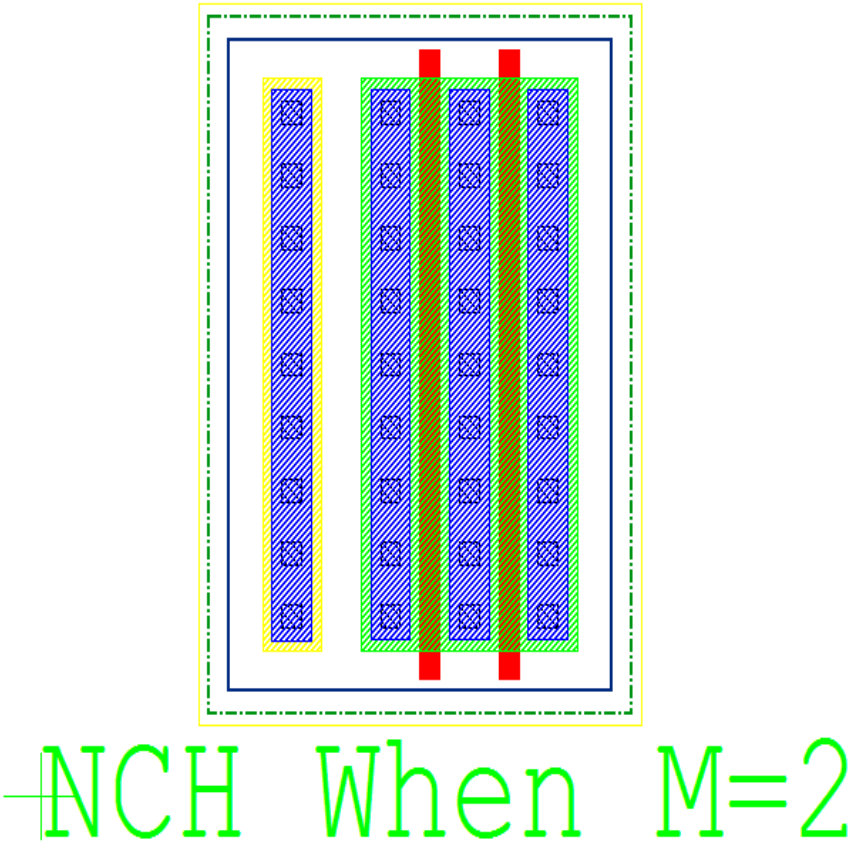


Fig 23. Layout of N channel MOSFET

❑ Resistor

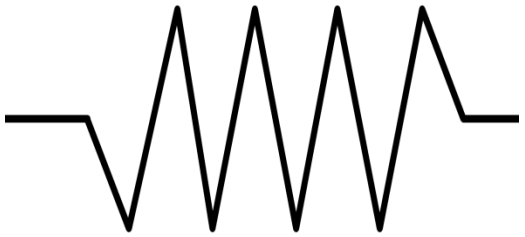


Fig 24. Resistor

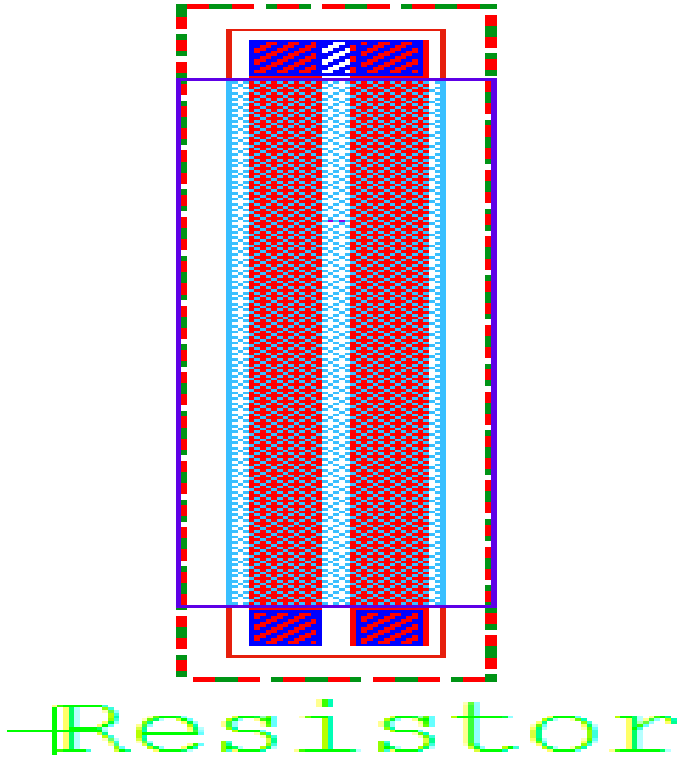


Fig 25. Layout of Resistor

❑ DNWELL Capacitor

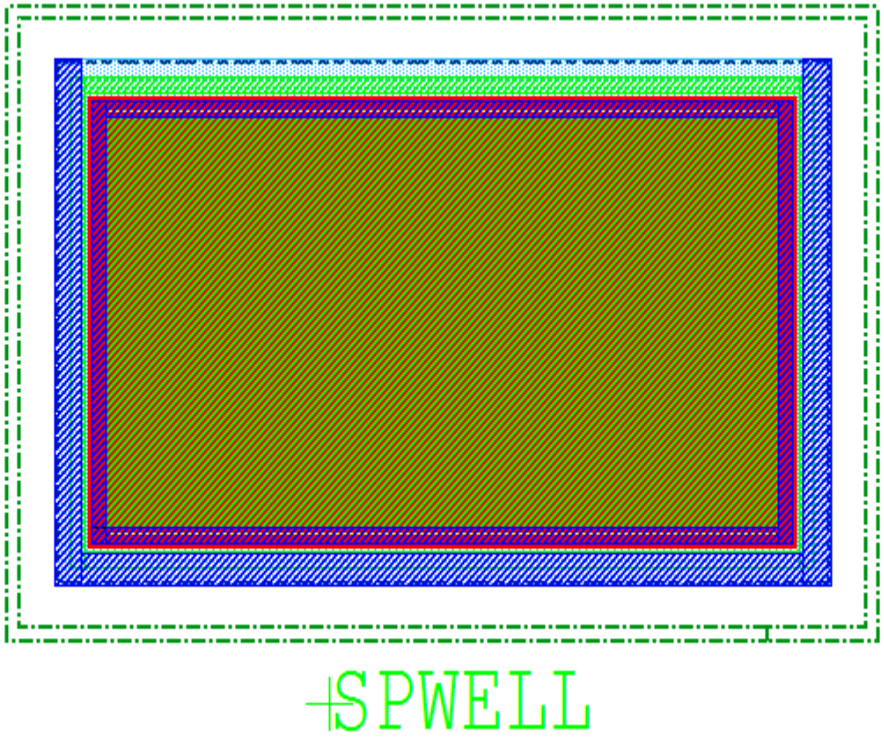


Fig . DNWELL Capacitor

❑ SPWELL Capacitor

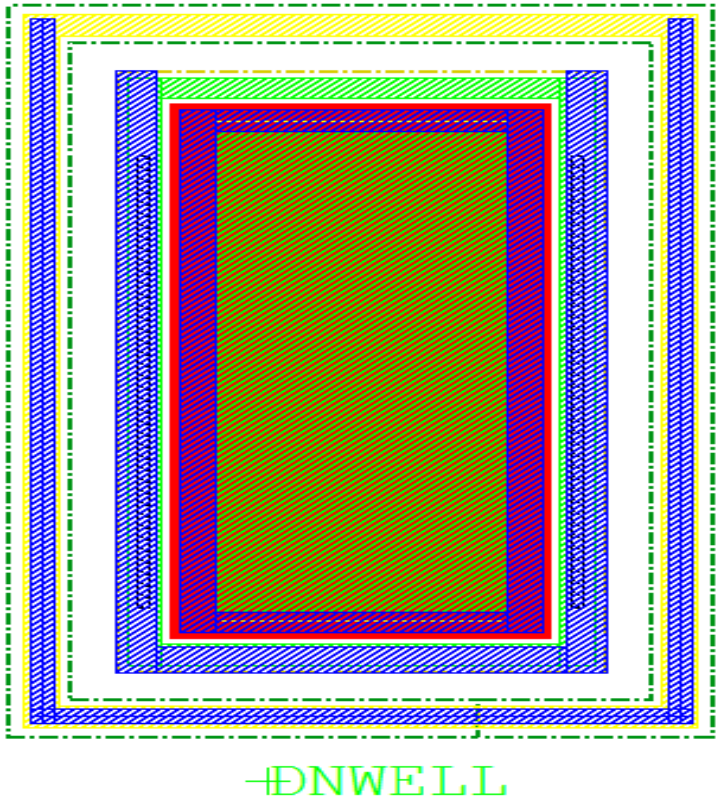


Fig 27. SPWELL Capacitor

❑ RC Circuit

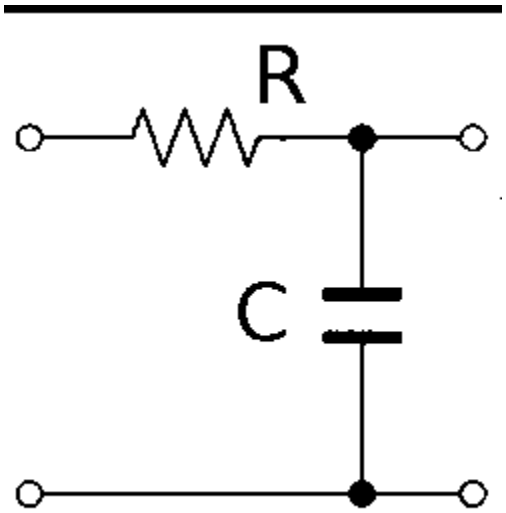


Fig 28. RC Circuit

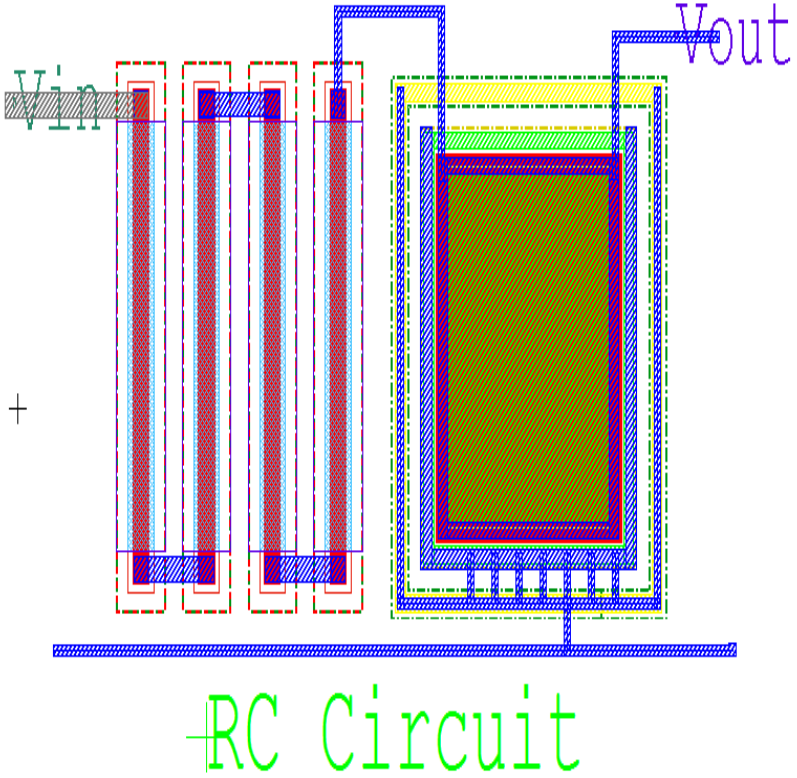


Fig 29. RC Layout

❑ Inverter

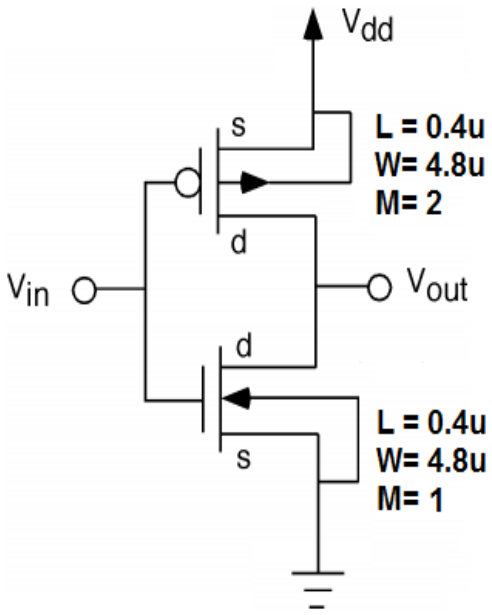


Fig 30. Inverter Circuit

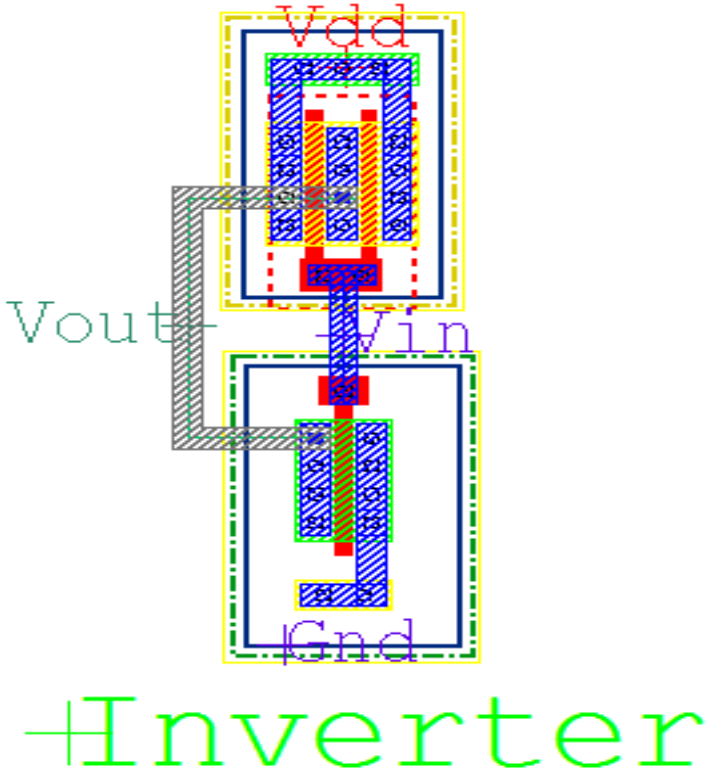
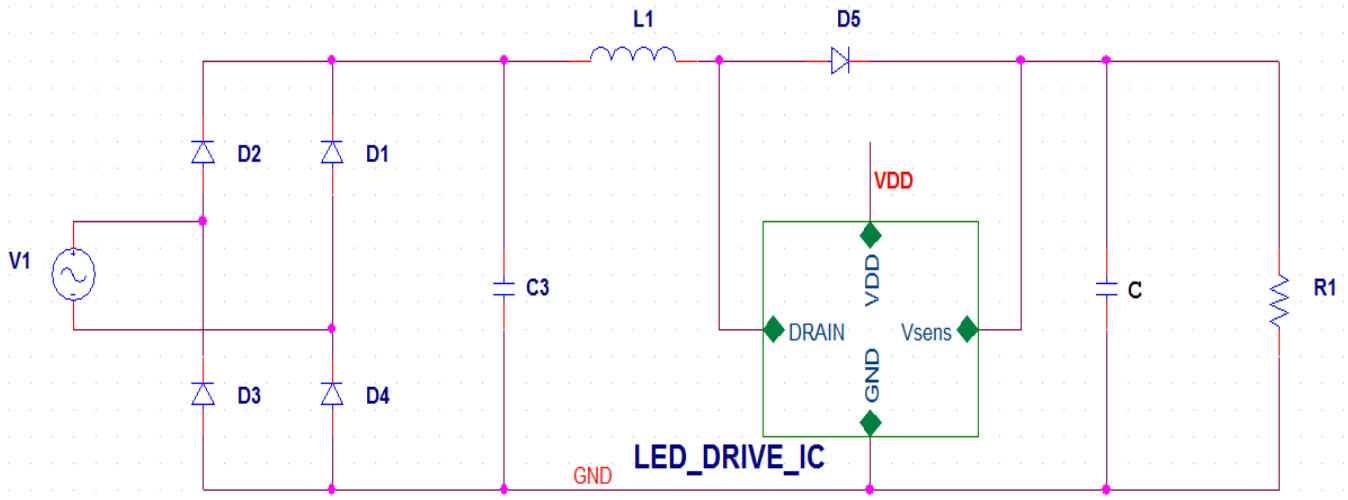


Fig 31. Inverter Layout



Ic in circuit system

❖Block diagram of system

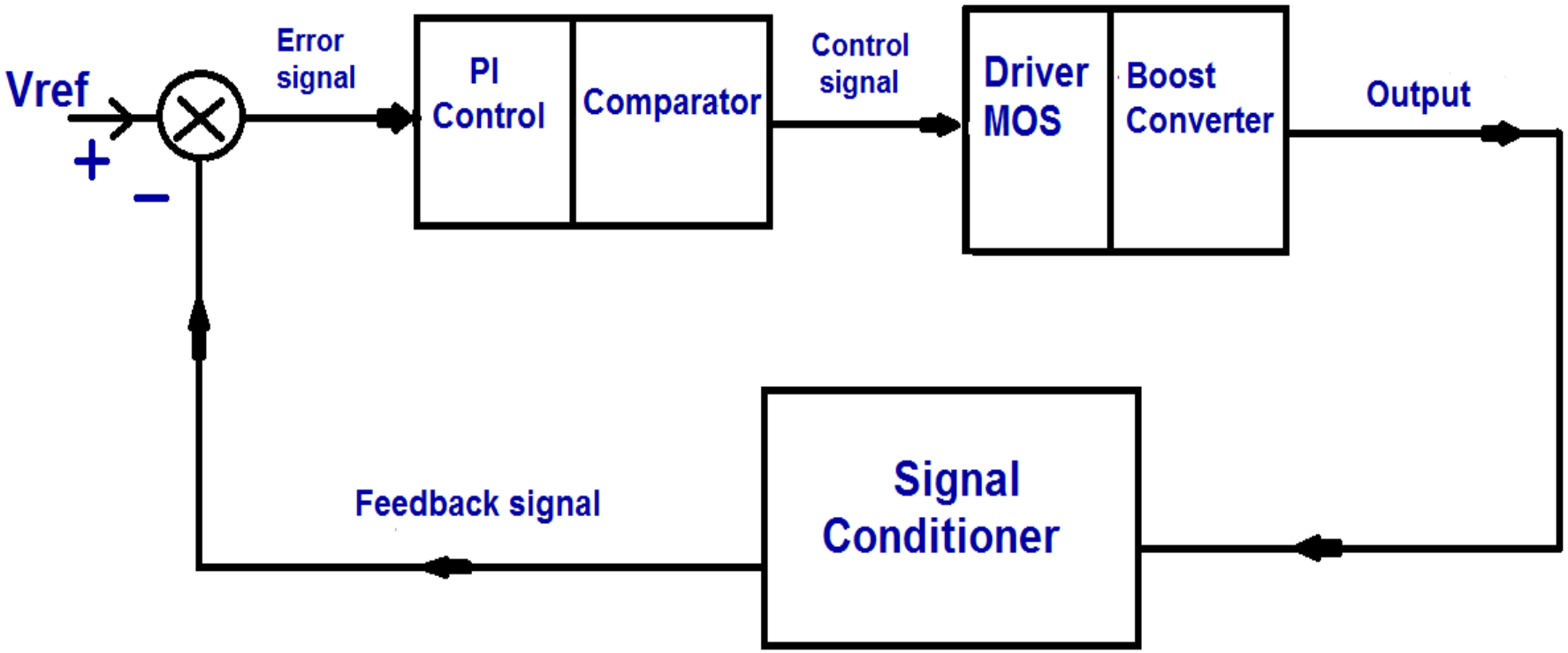
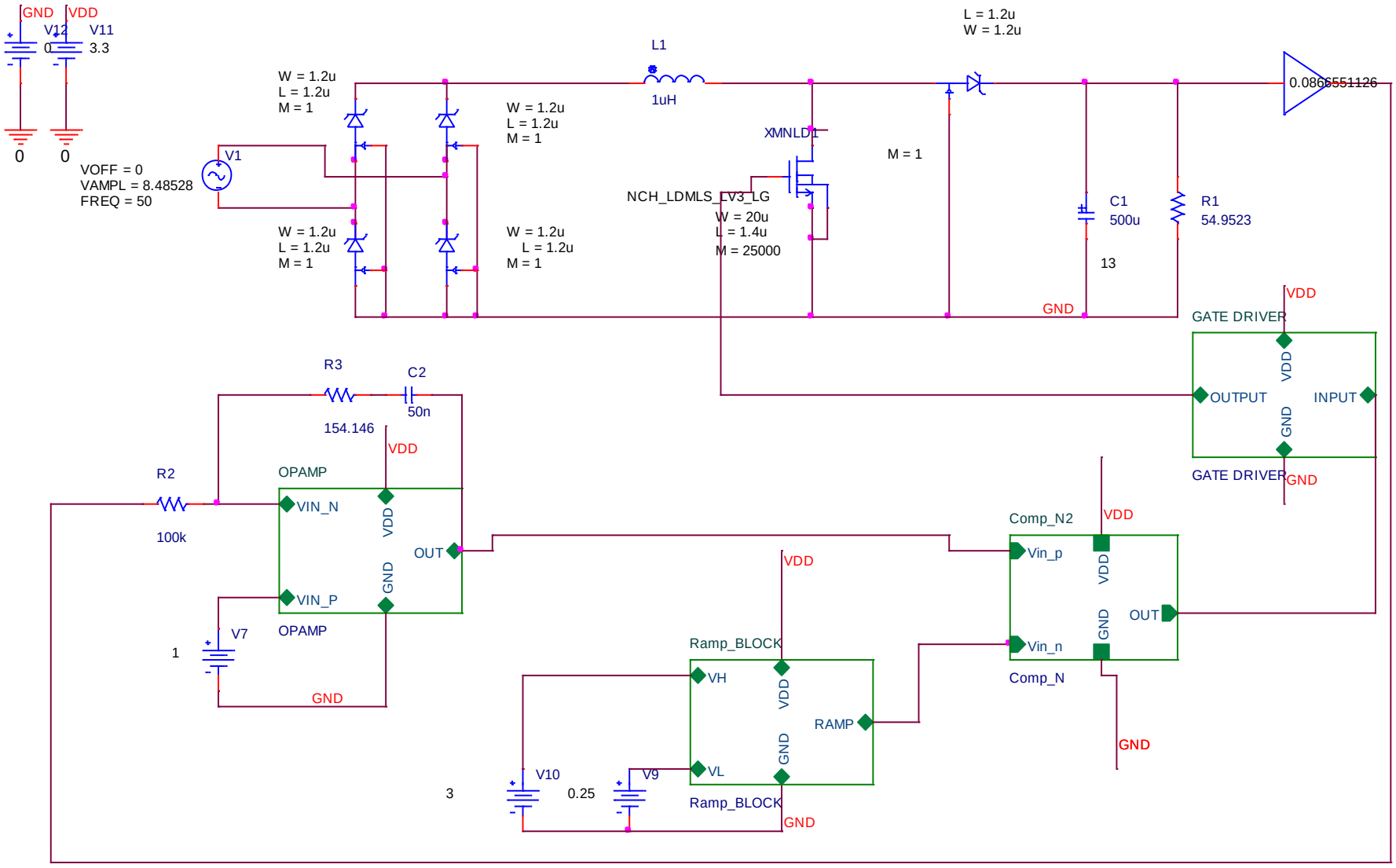


Fig 37. Block Diagram of System



Block of system

❖ System design

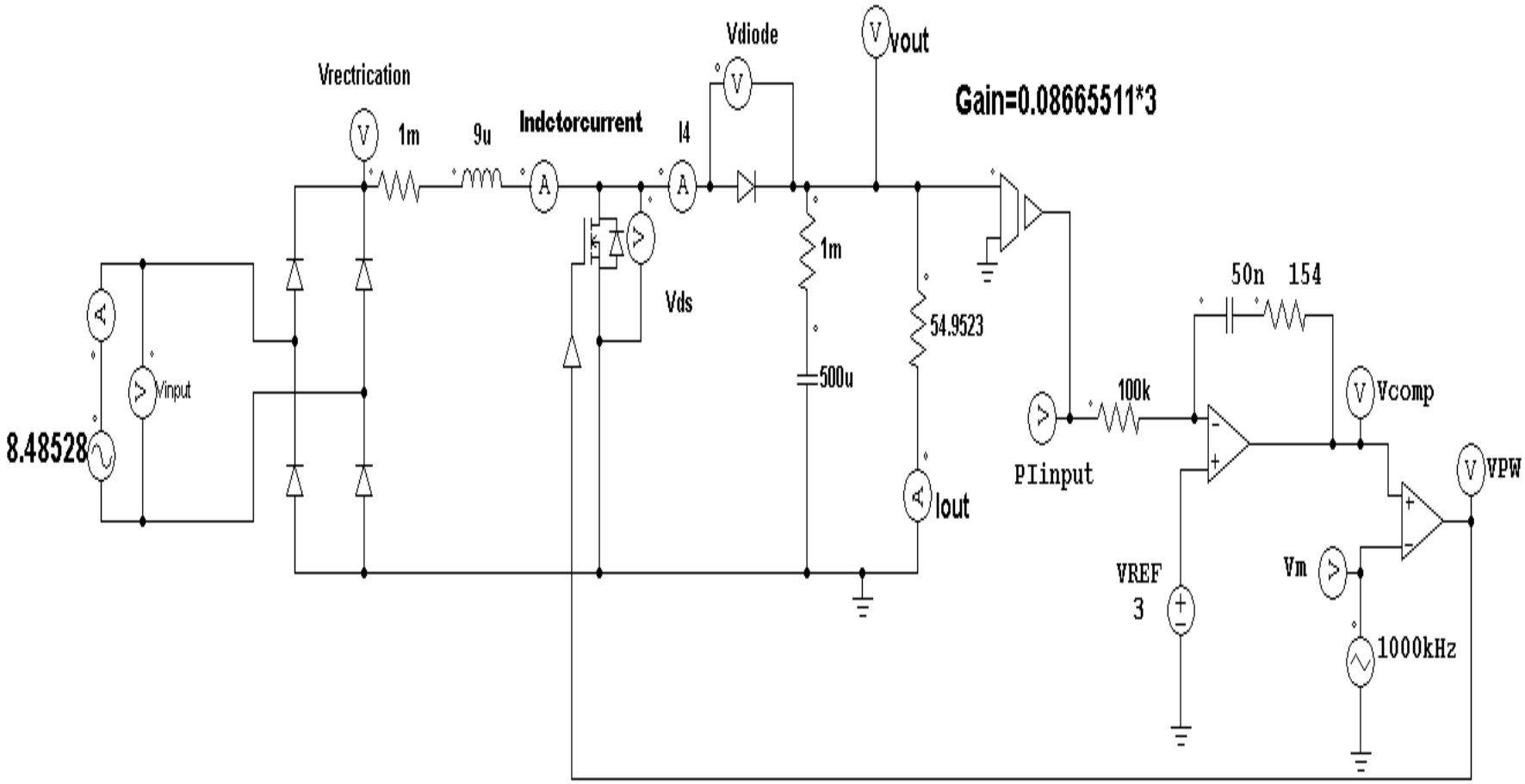
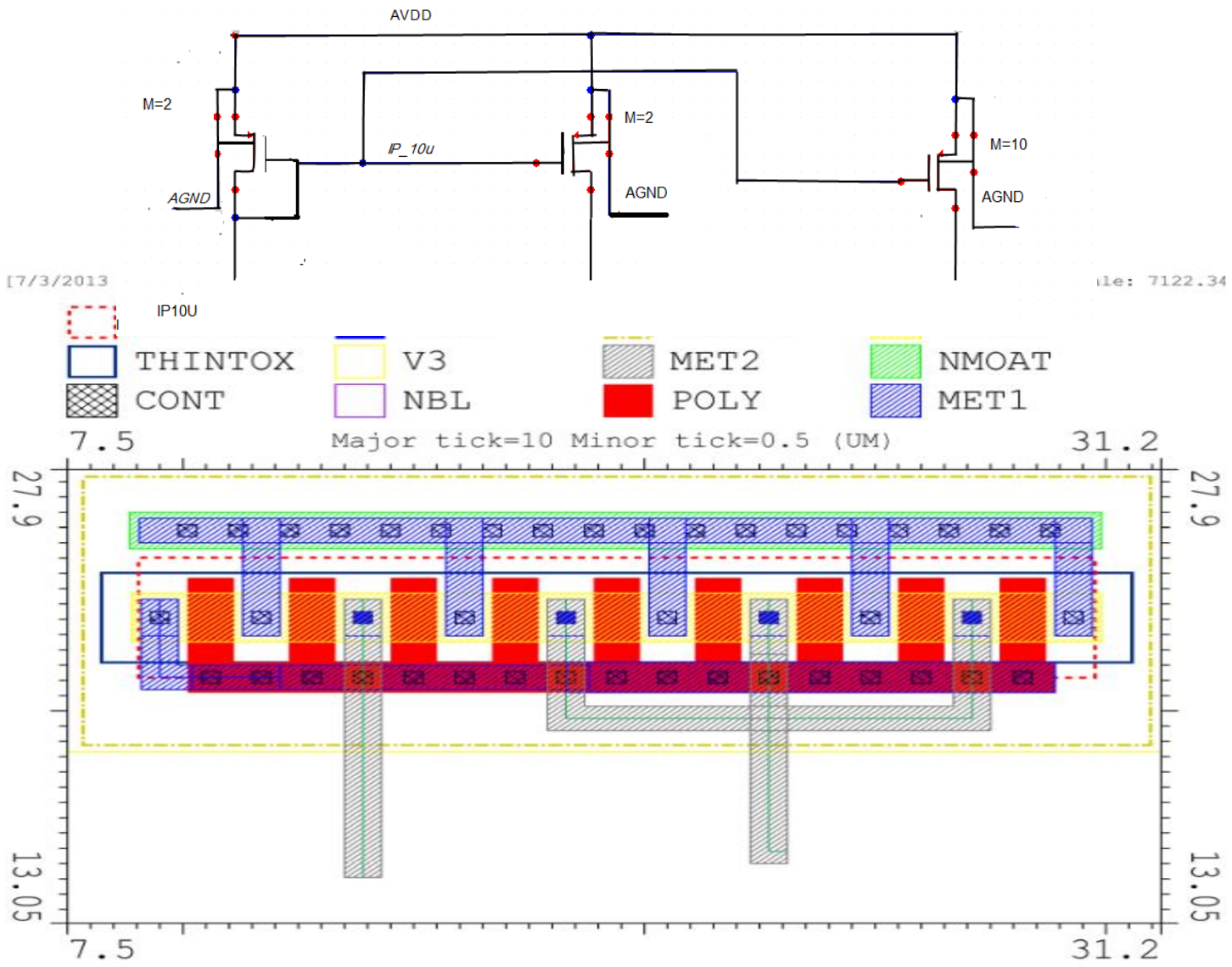


Fig 38.System with feedback

❑ Current mirror



❑ Differential Amplifier

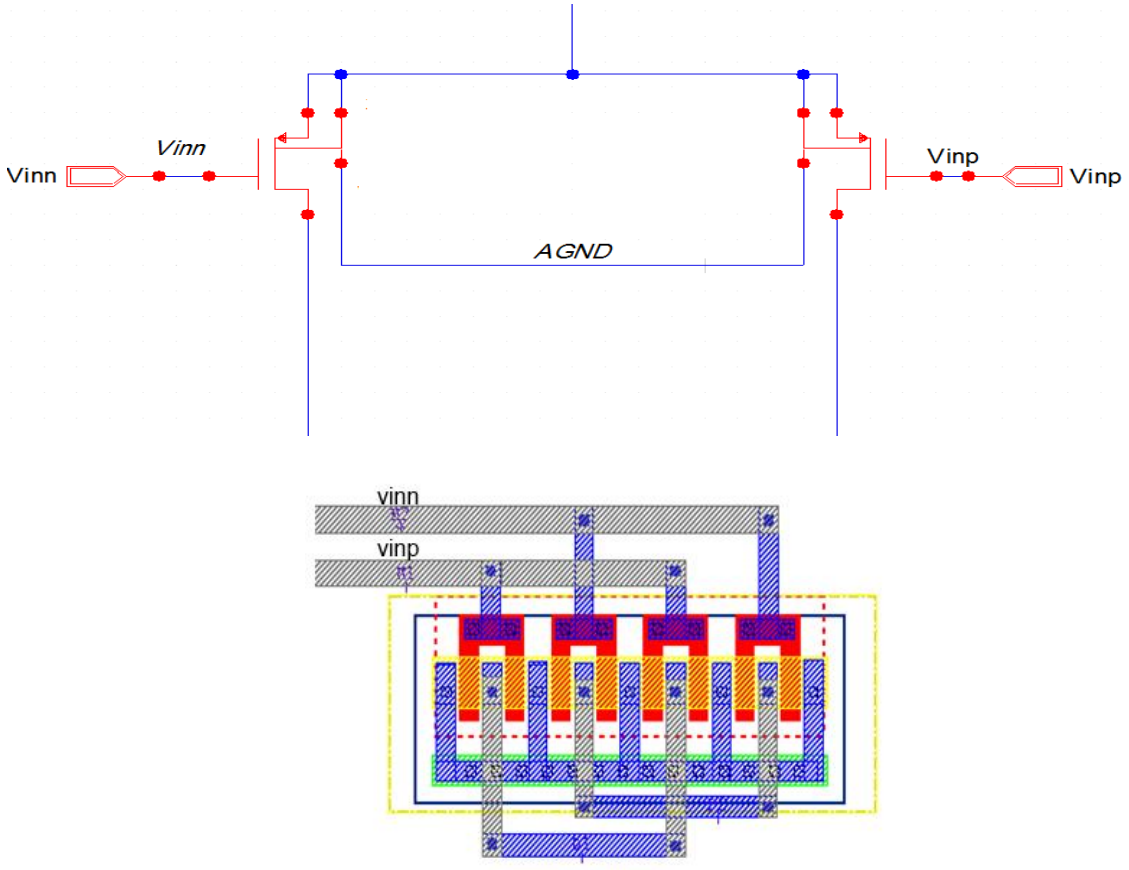


Fig 33. Differential Amplifier

❑ Operational Amplifier

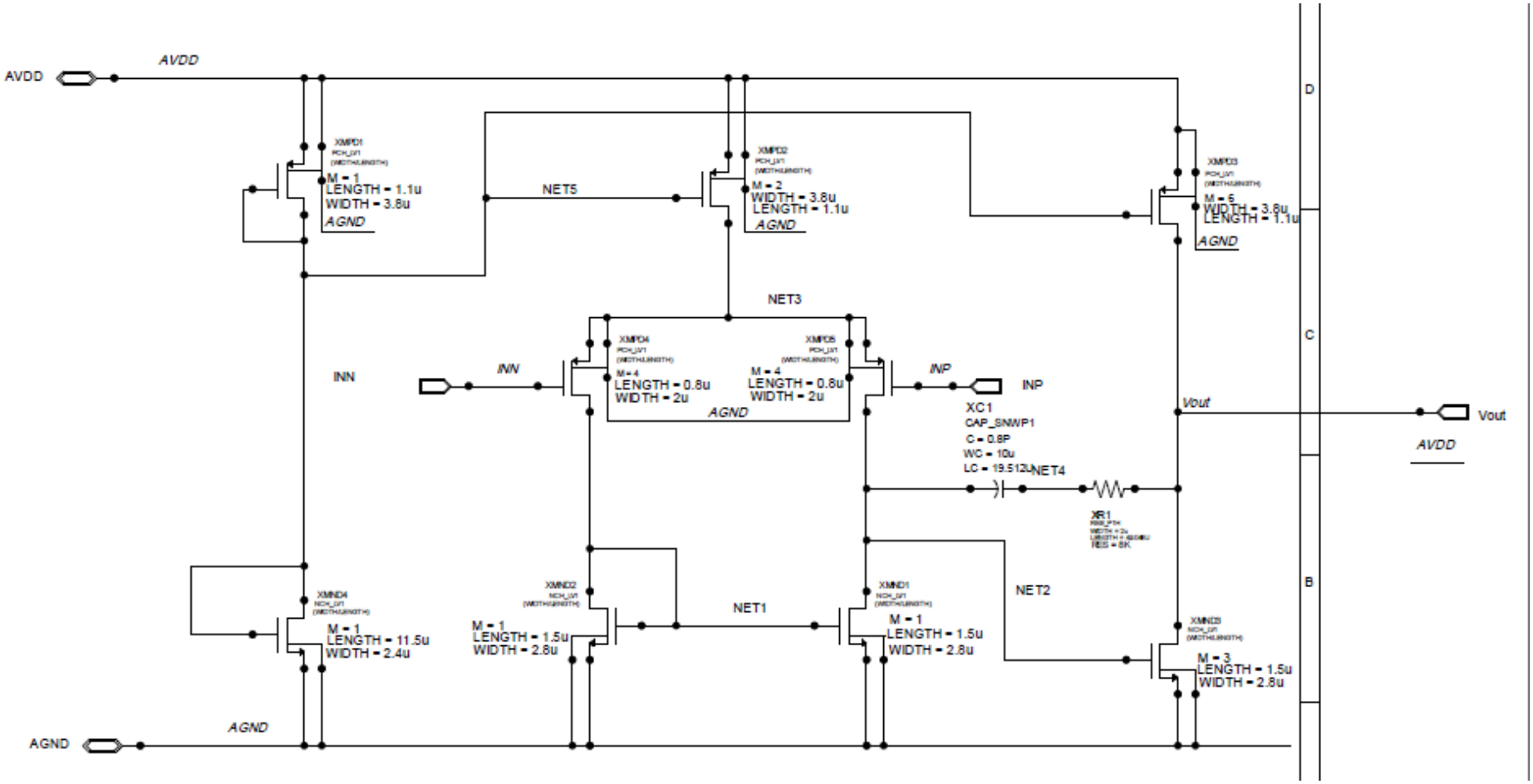


Fig 35. Operational Amplifier

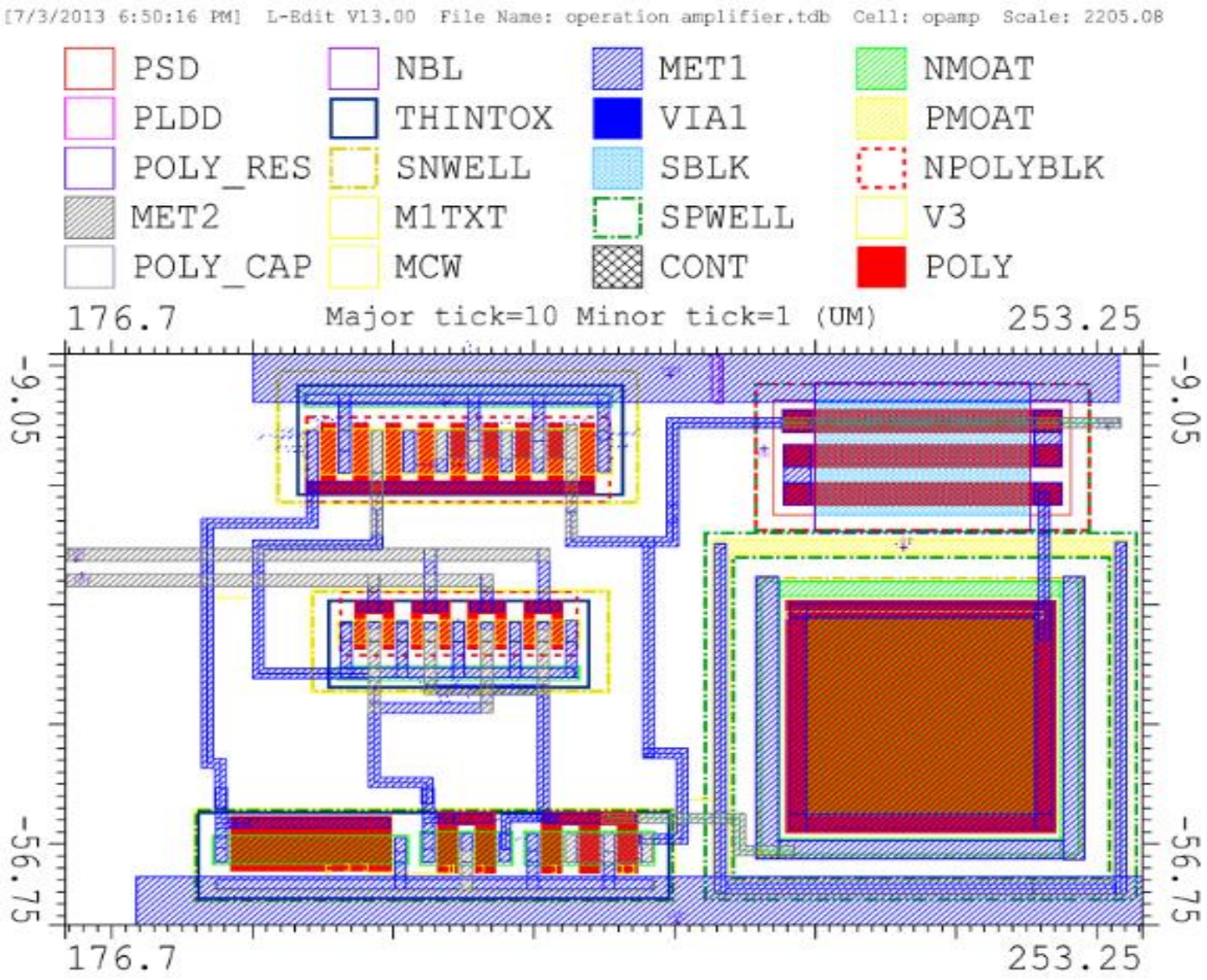
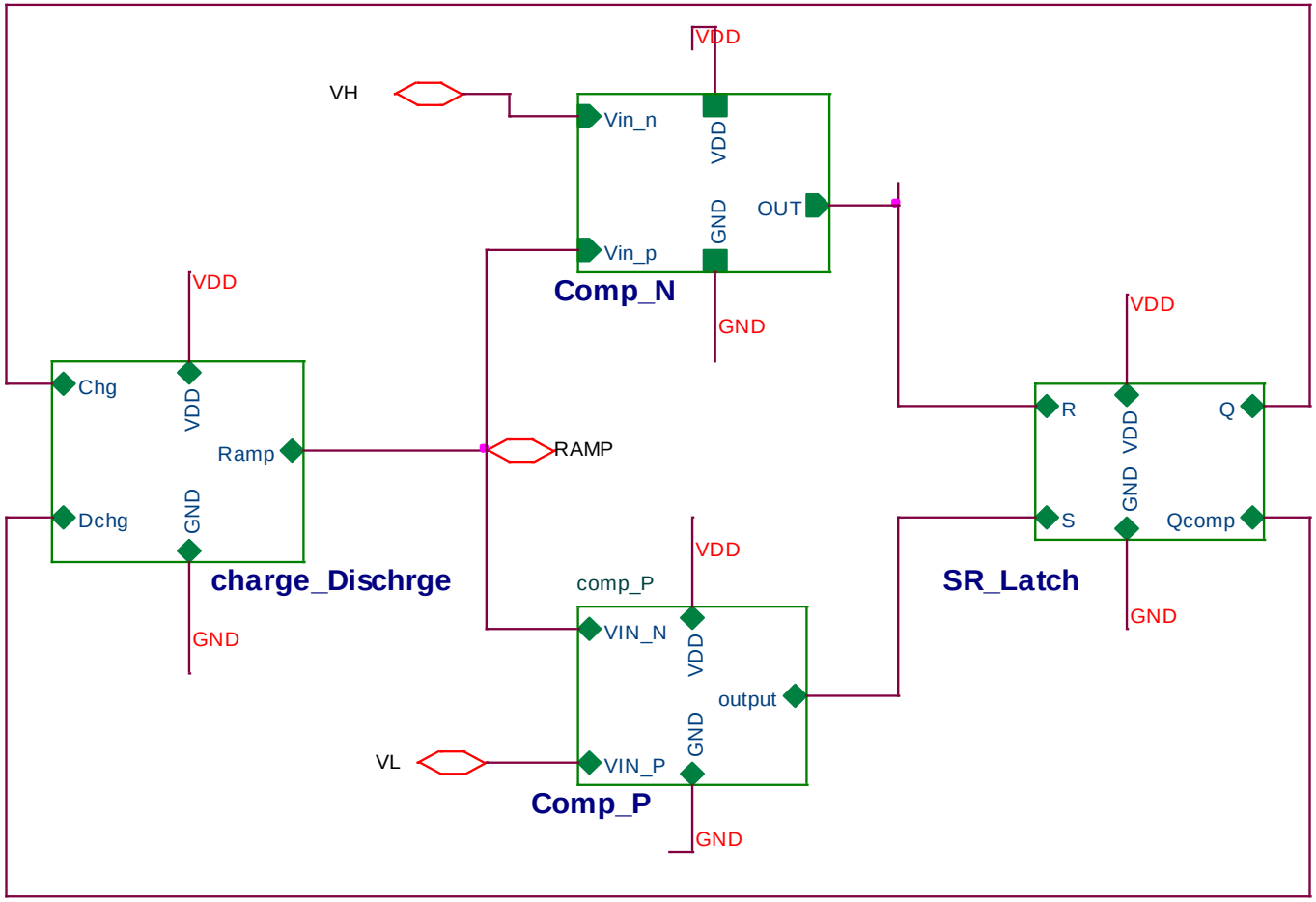
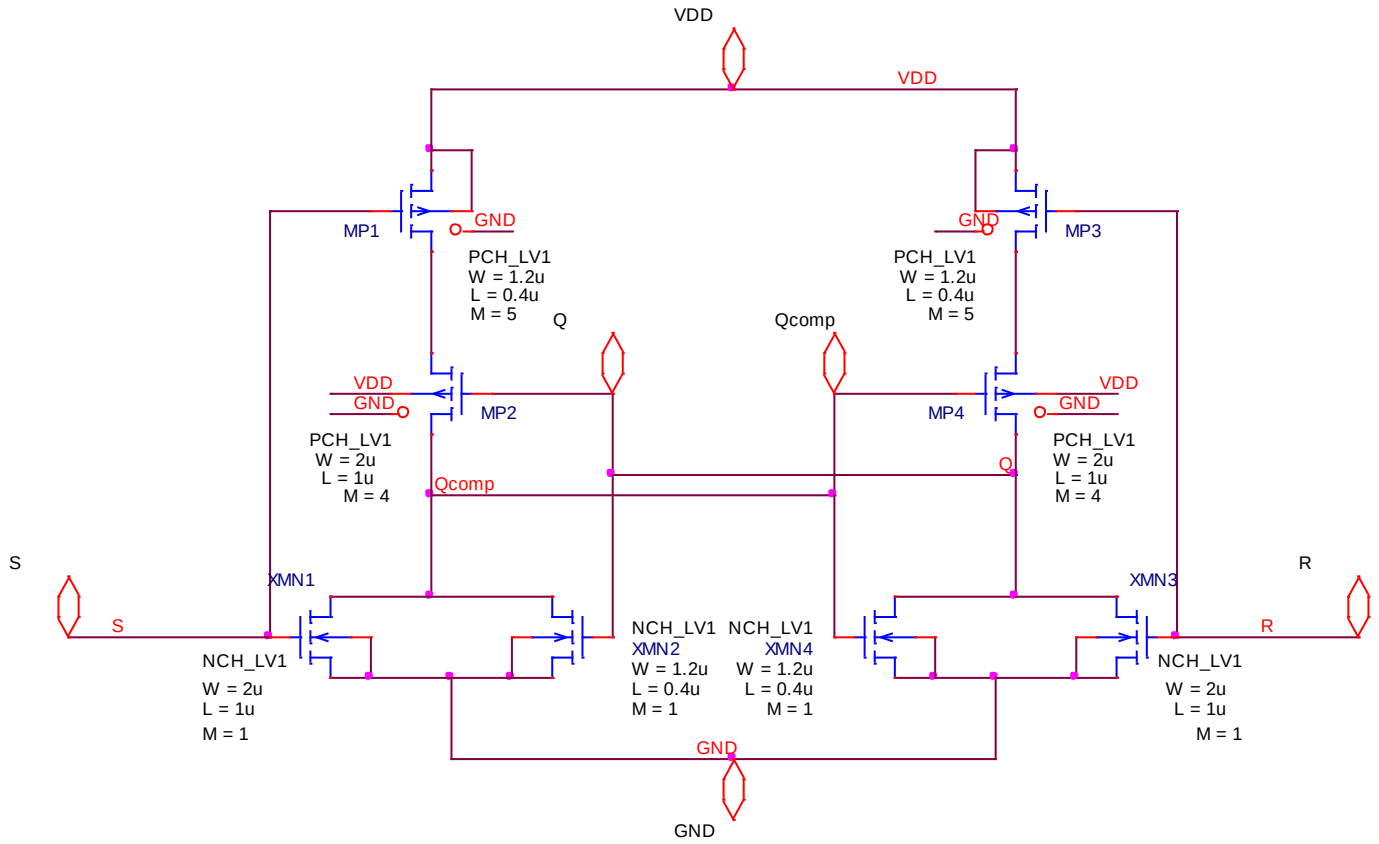


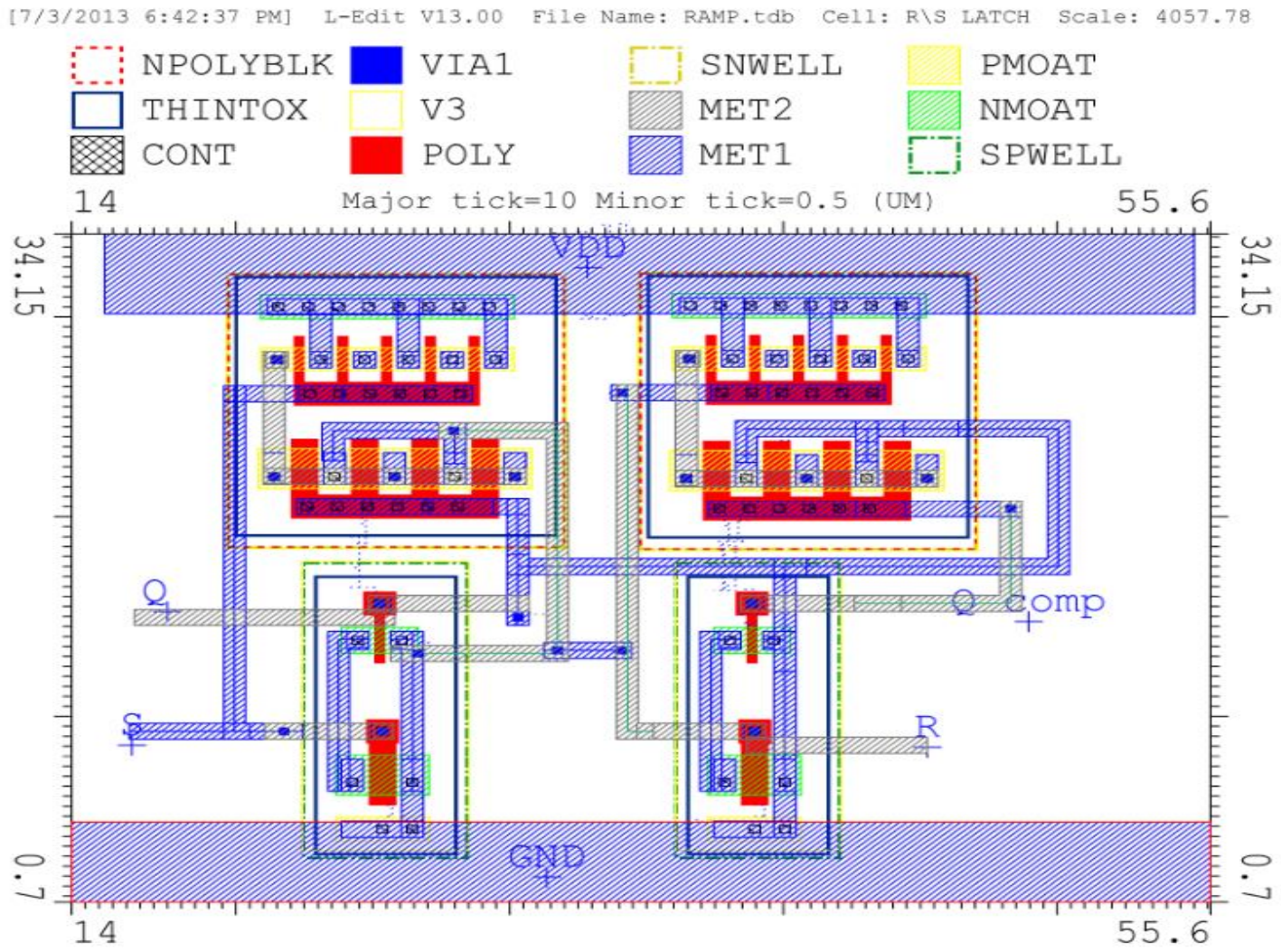
Fig 36. The layout of Operational Amplifier



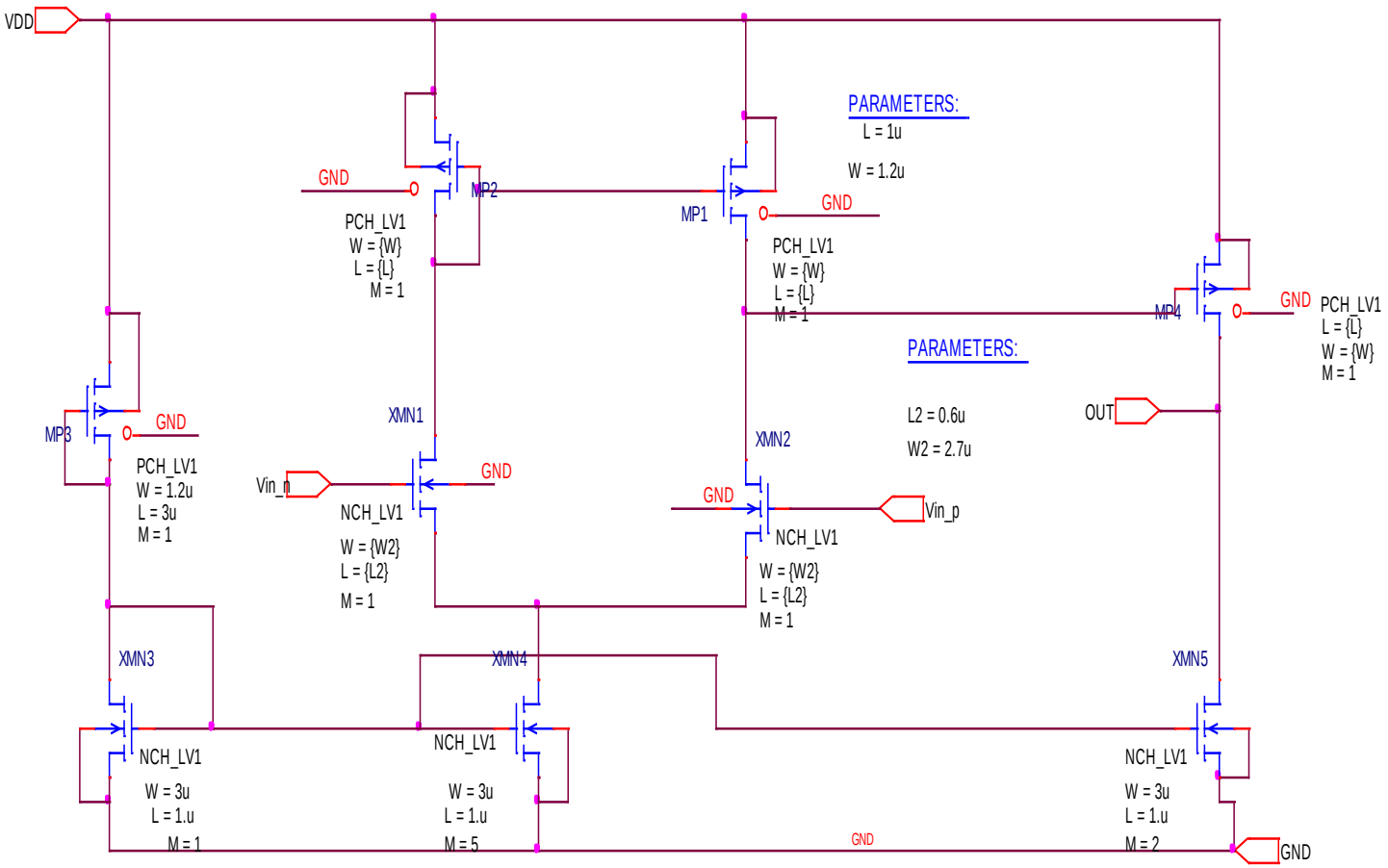
- **Block of Ramp signals**



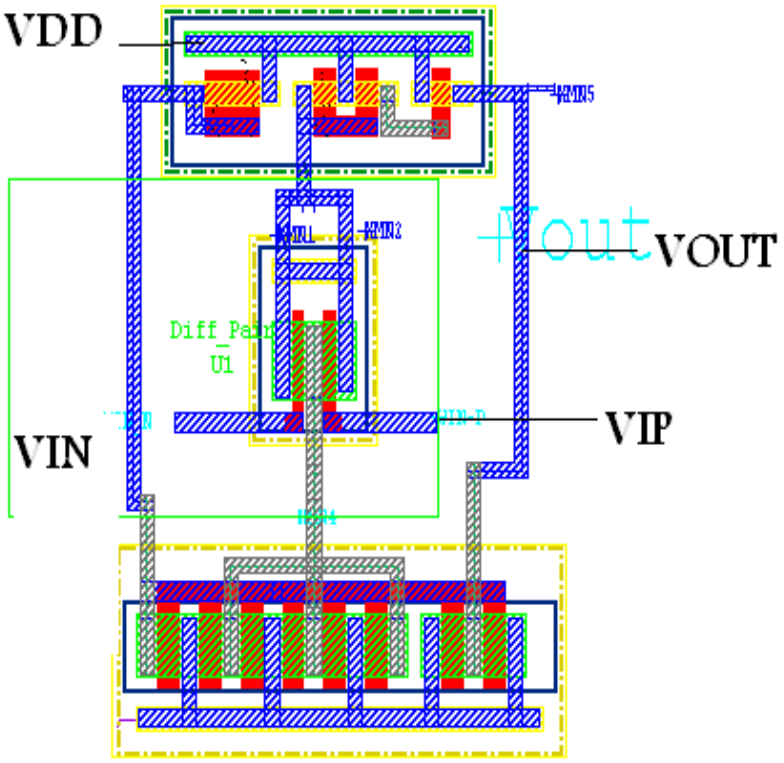
Circuit of RS



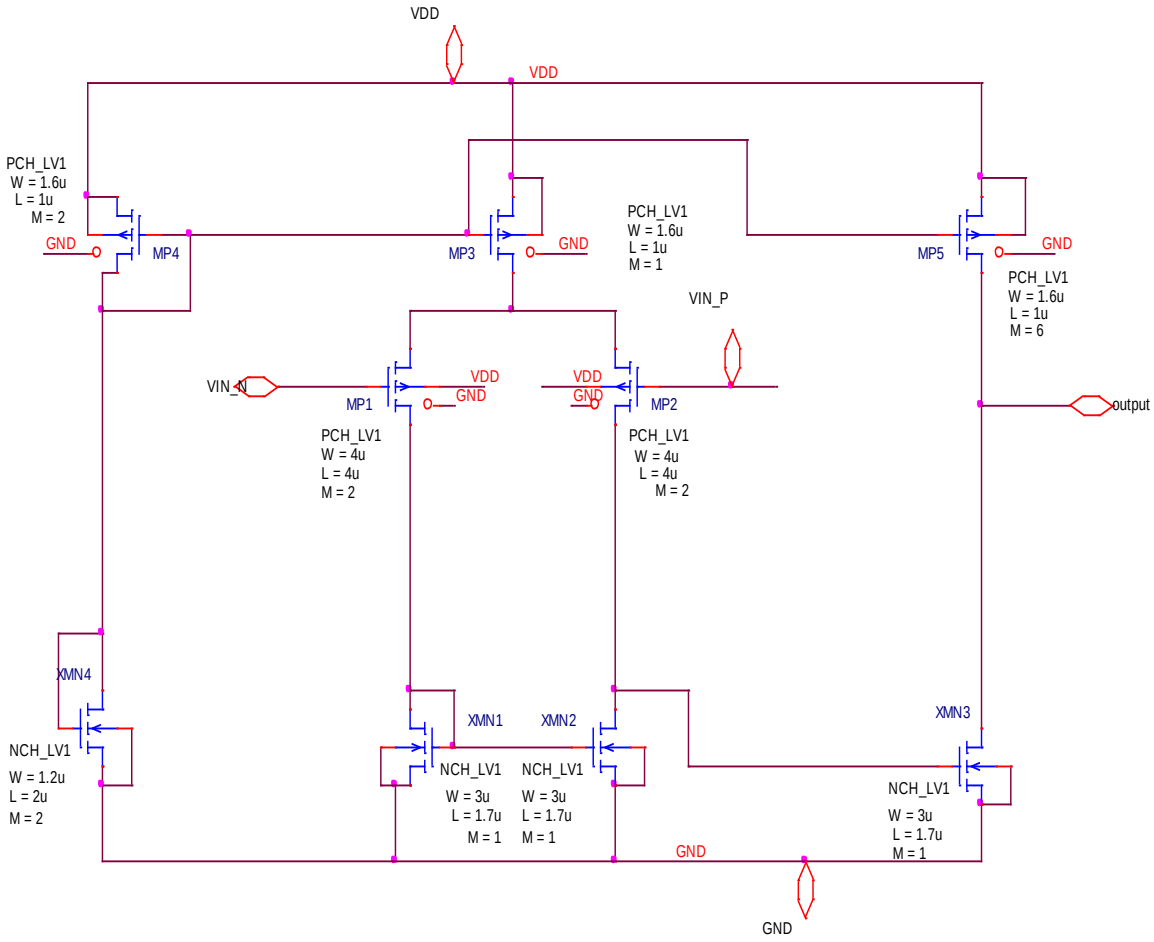
R S latch figure 3.7



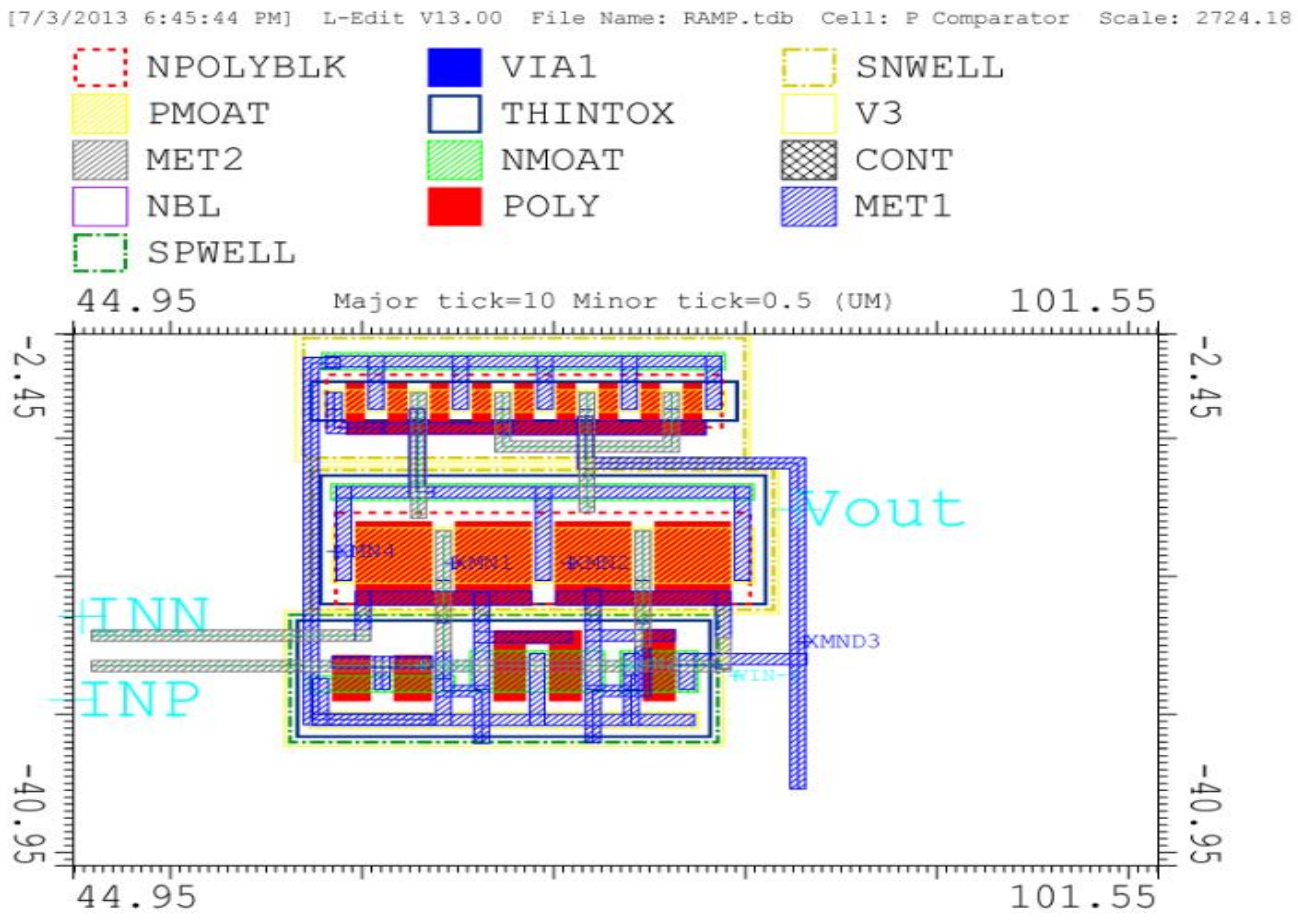
N comparator



- Layout of n comparator

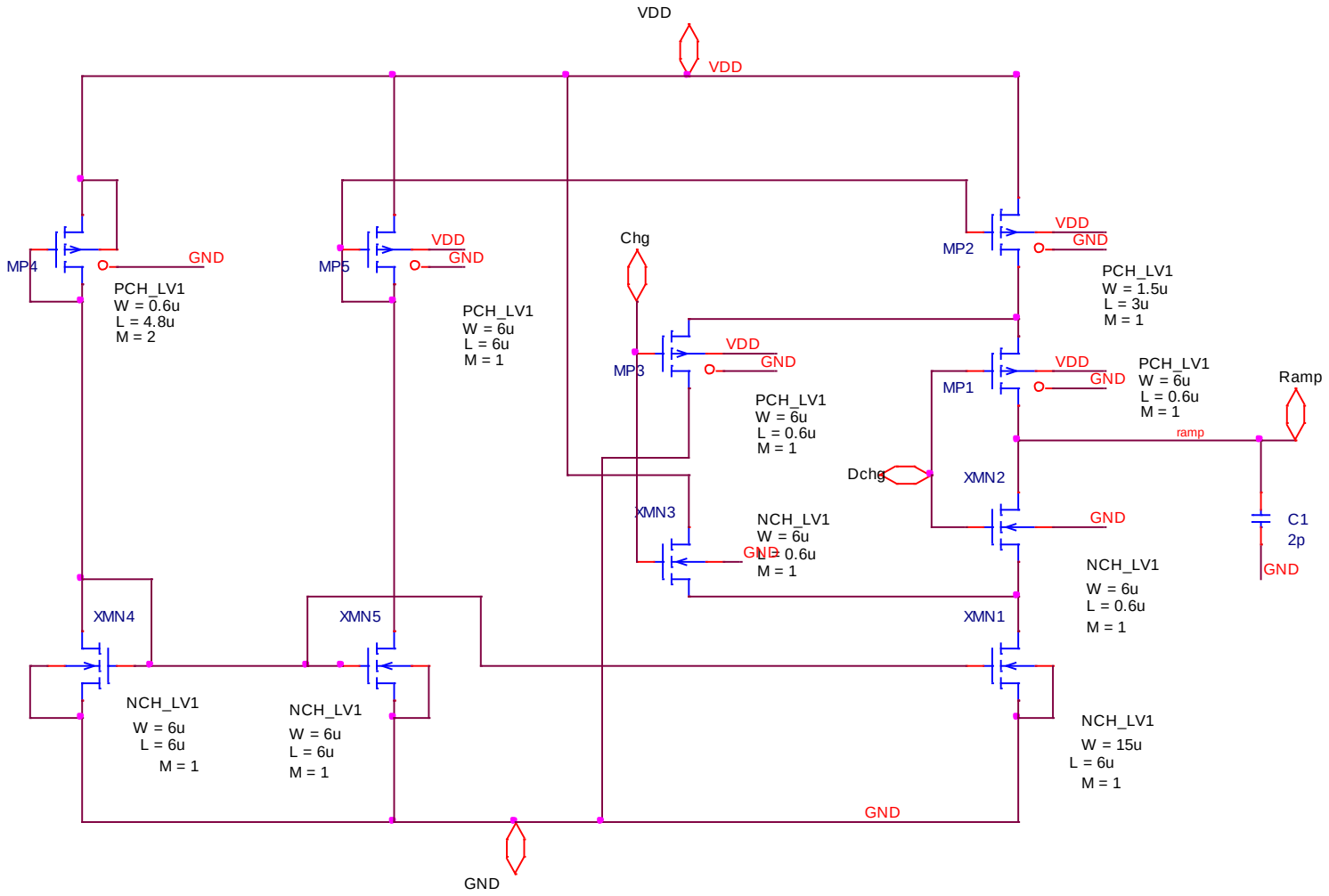


P comparator

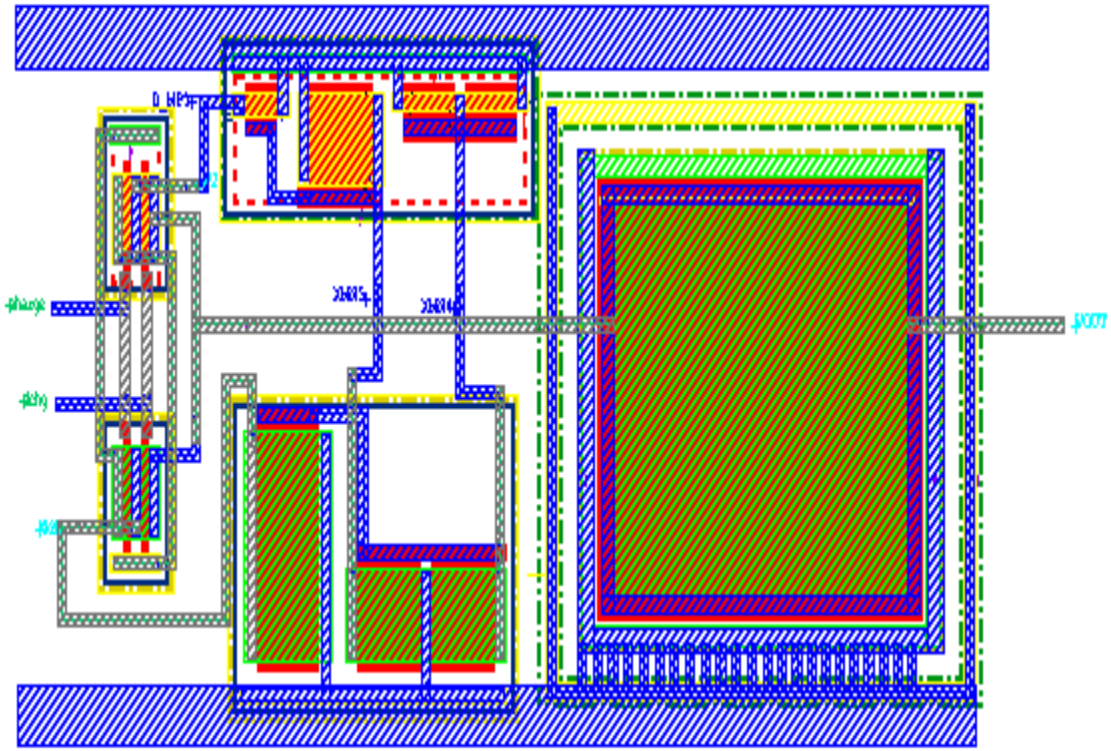


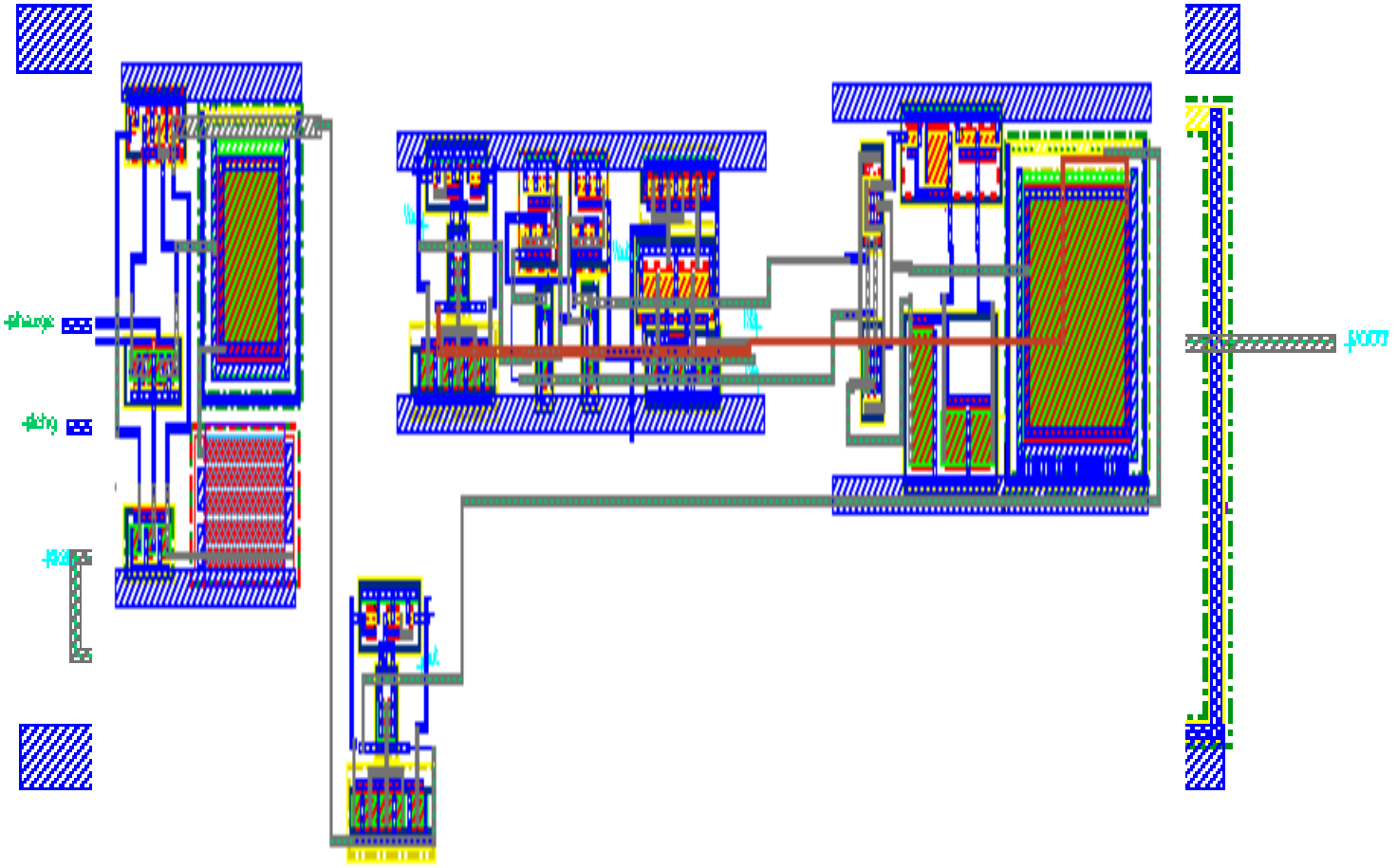
- **Lay out p comparator**

Charge and Discharge



The Layout of charge and Discharge





- Layout Control circuit

❖ Practical circuit

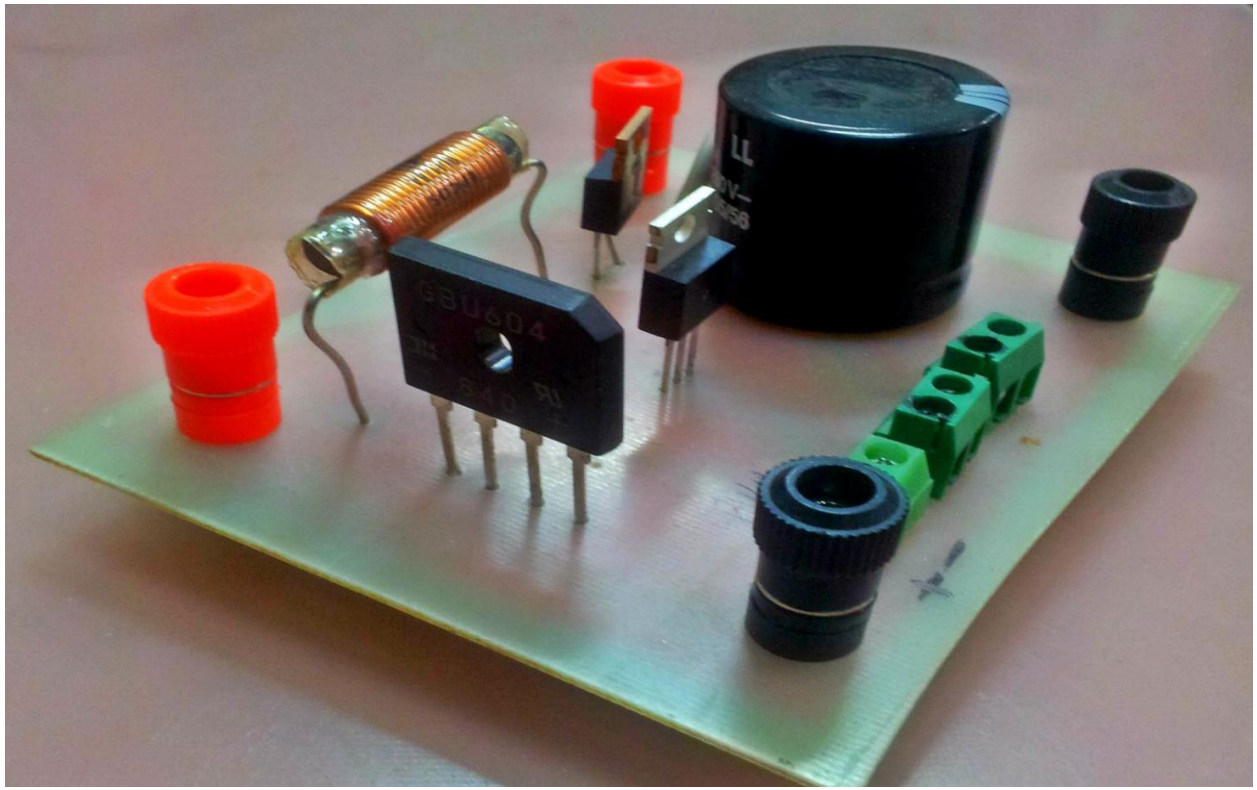


Fig 39 . Power Stage

❖ Inductor Current

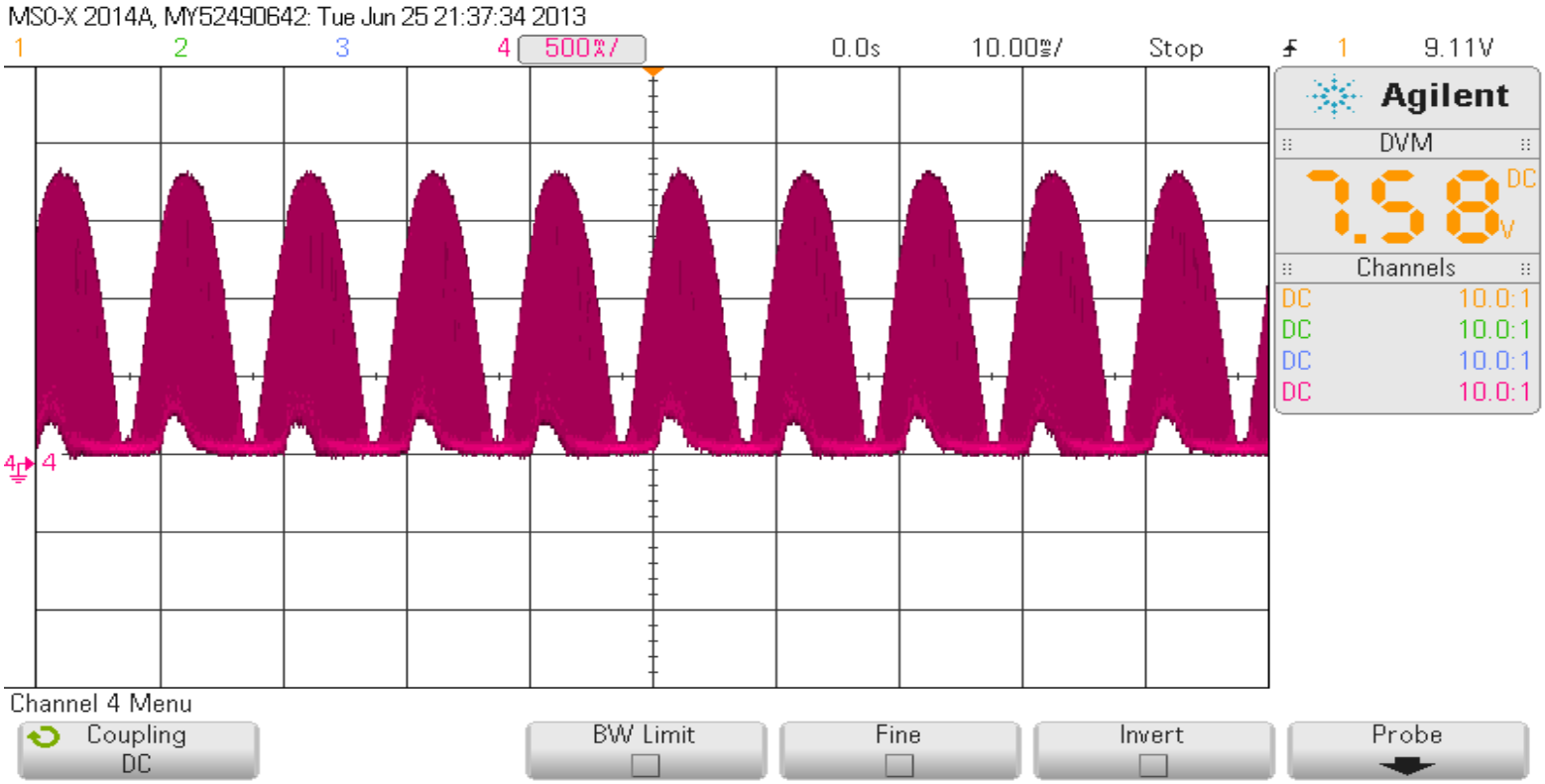


Fig 40 . Inductor Current

❖ Inductor Current (Zoomed)

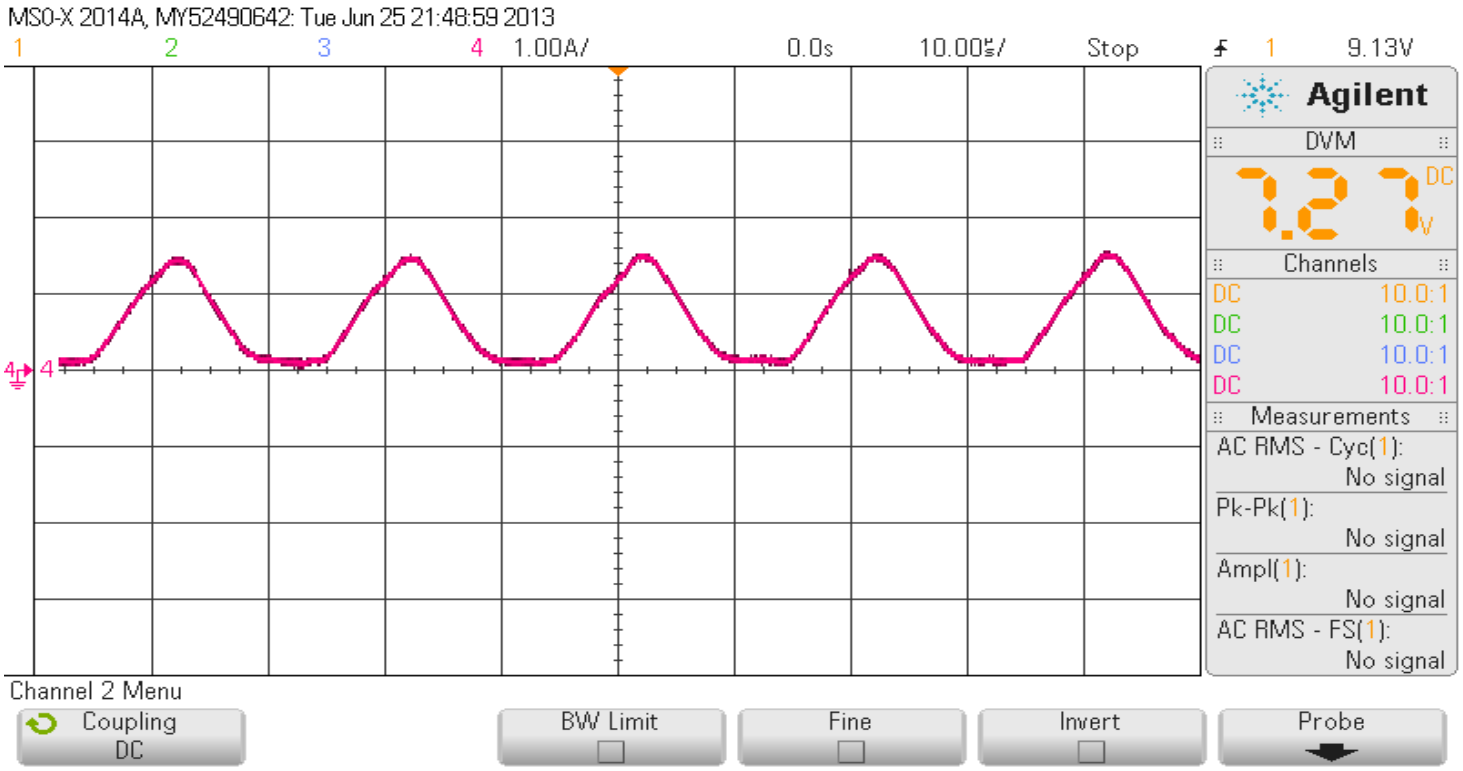


Fig 41 . Inductor Current (Zoomed)

❖ Output Voltage

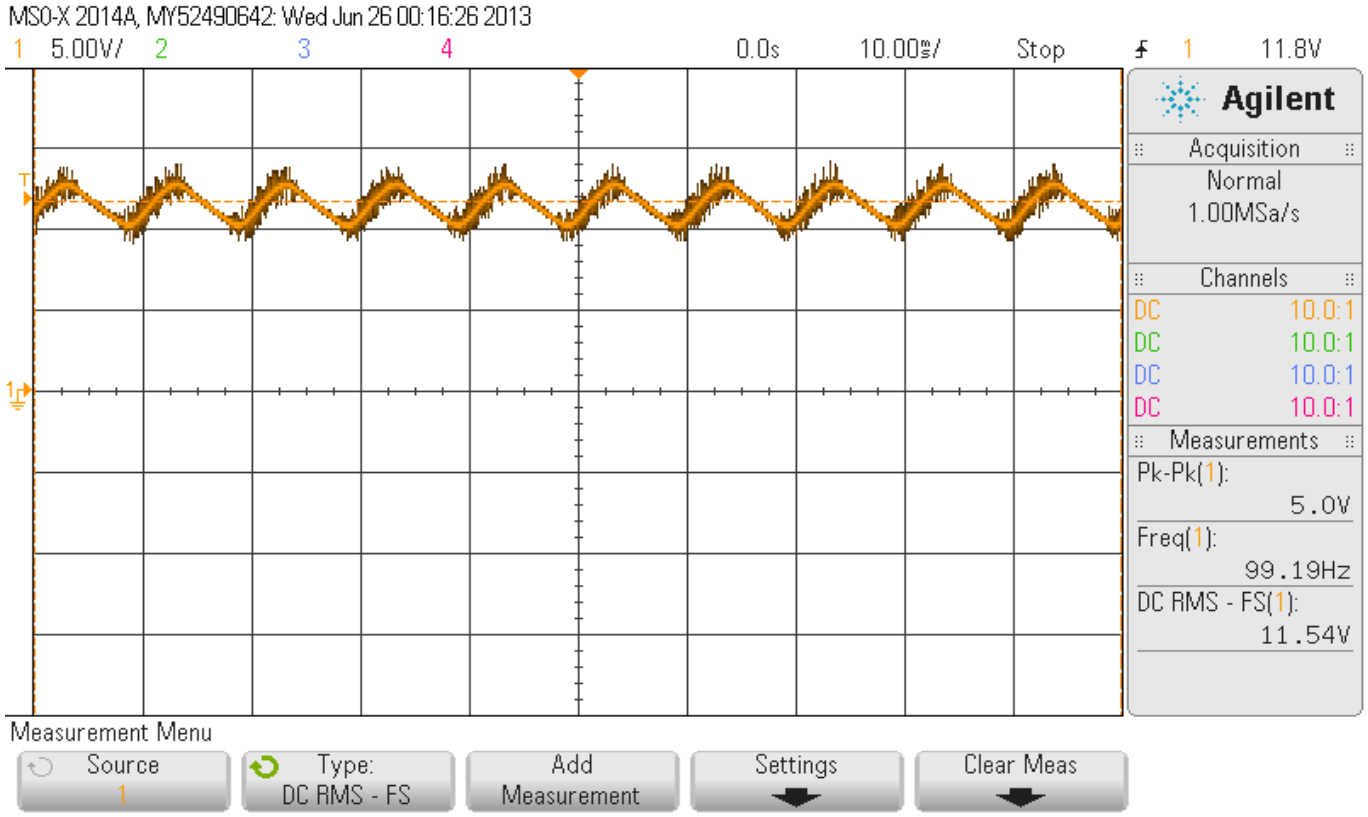


Fig 42 . Output Voltage

❖ Output Rectifier

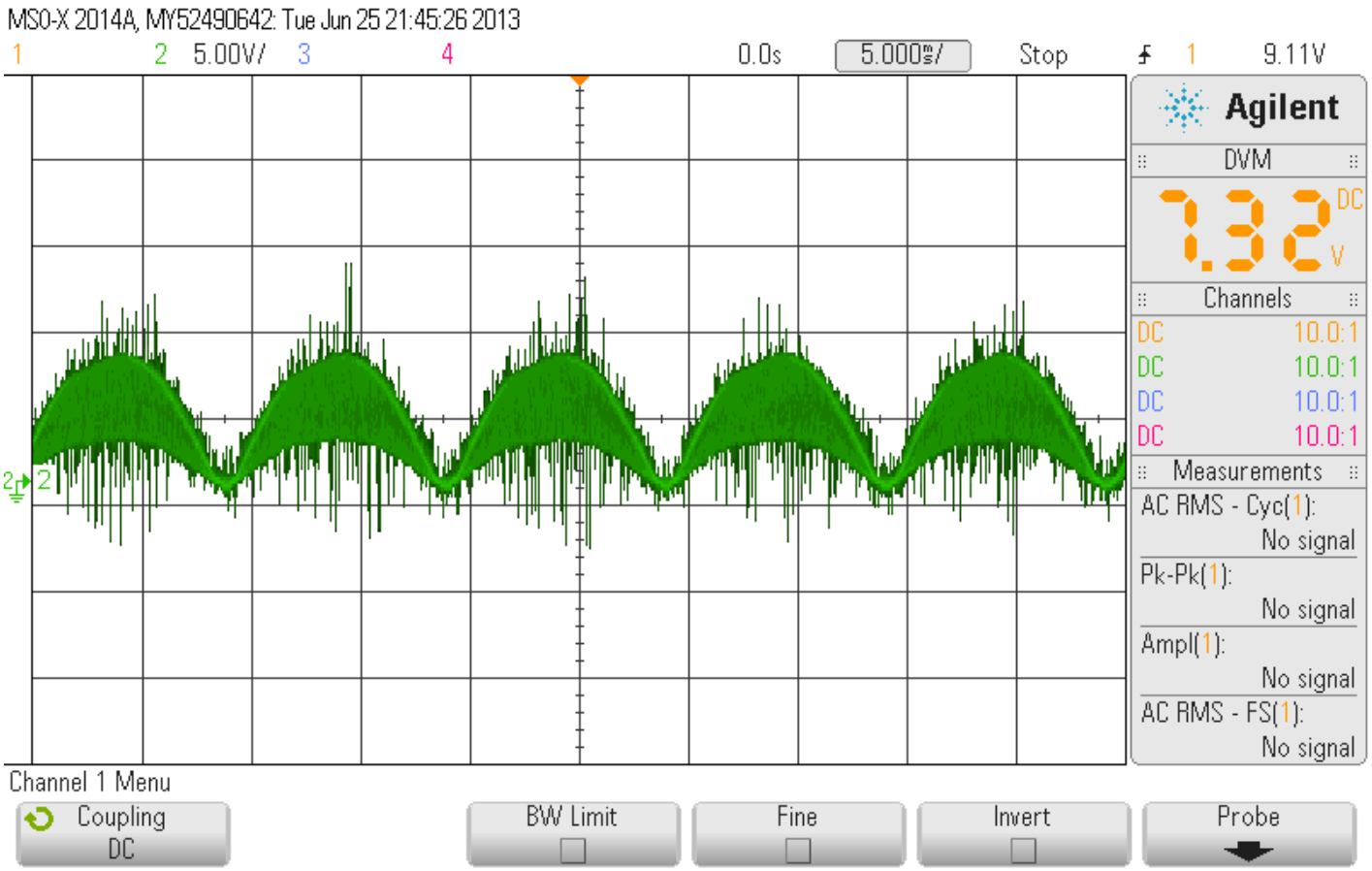


Fig 43 . Output Rectifier

❖ Drain Source Output

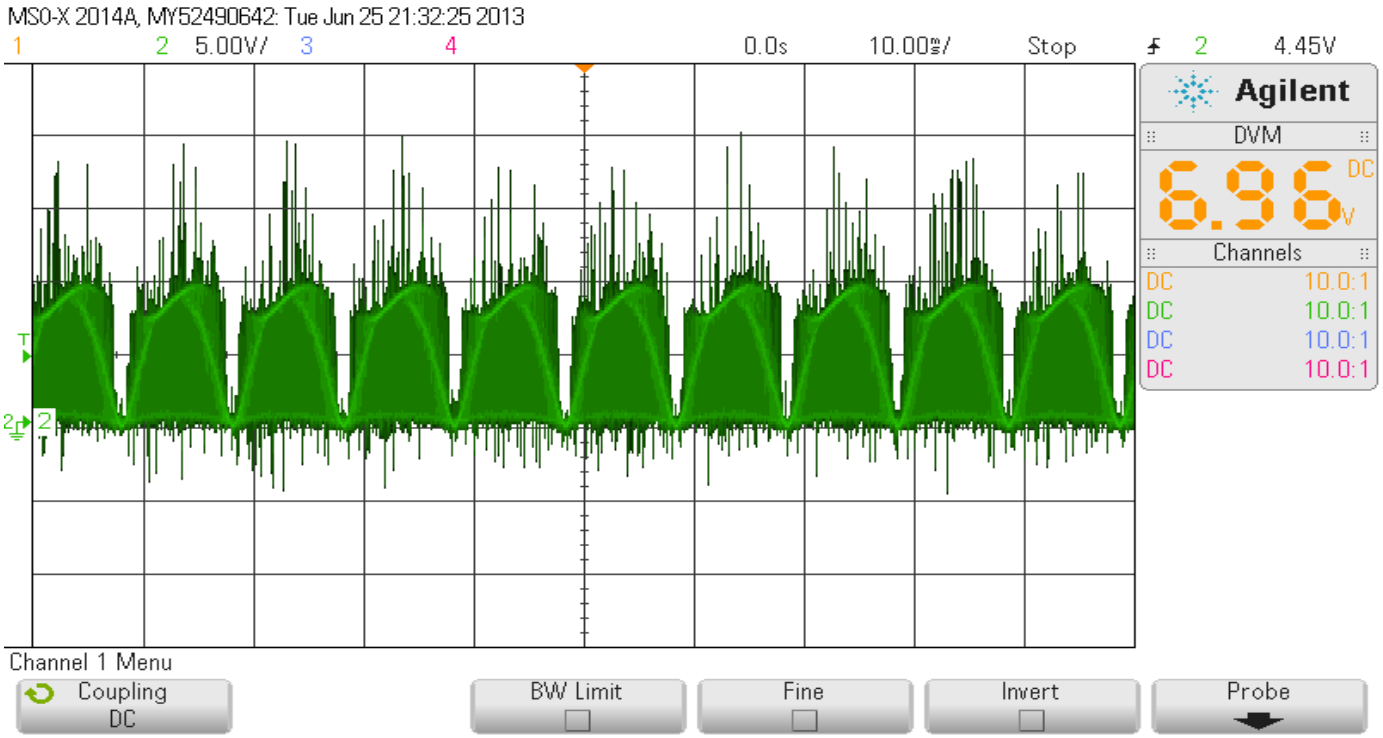


Fig 44. Drain Source Output

❖ PI Output &Output Voltage & Duty Cycle

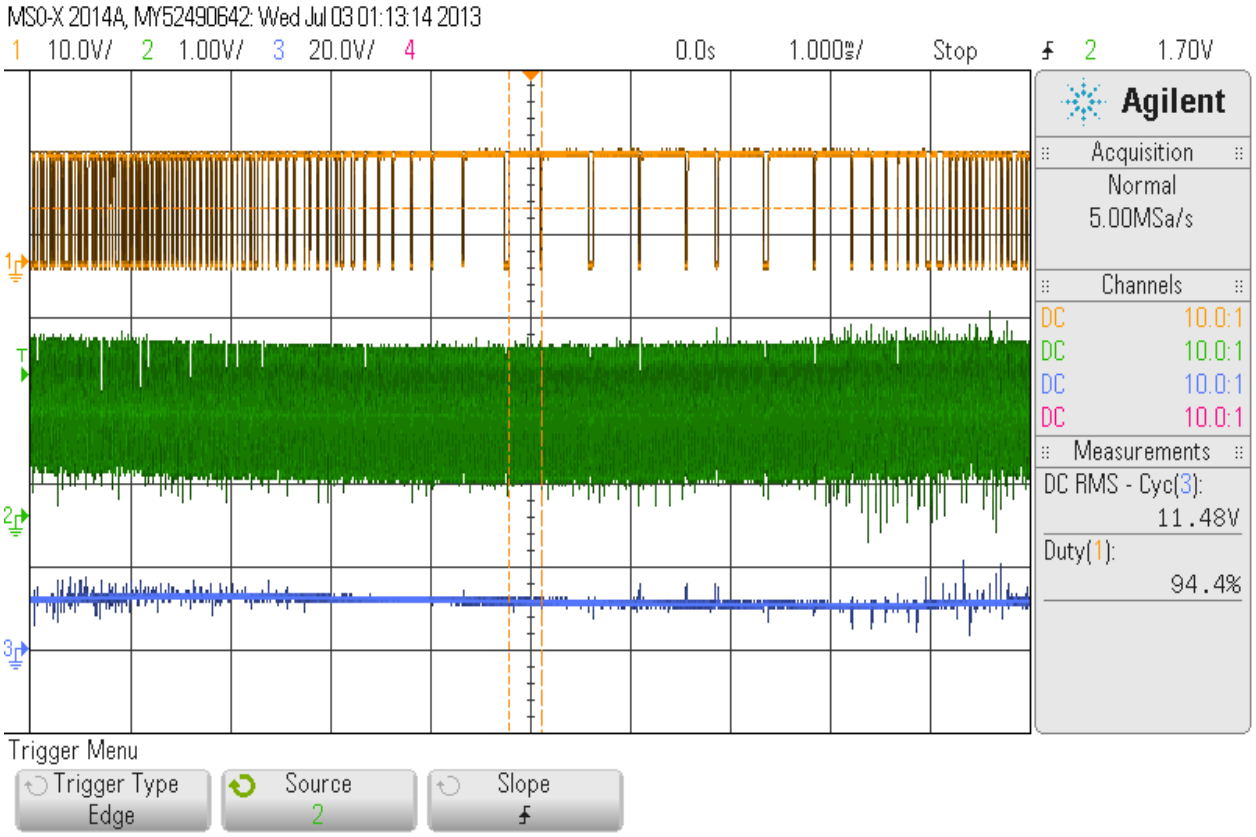


Fig 45 . PI Output Output Voltage Duty Cycle

❖ PI Output &Output Voltage & Duty Cycle

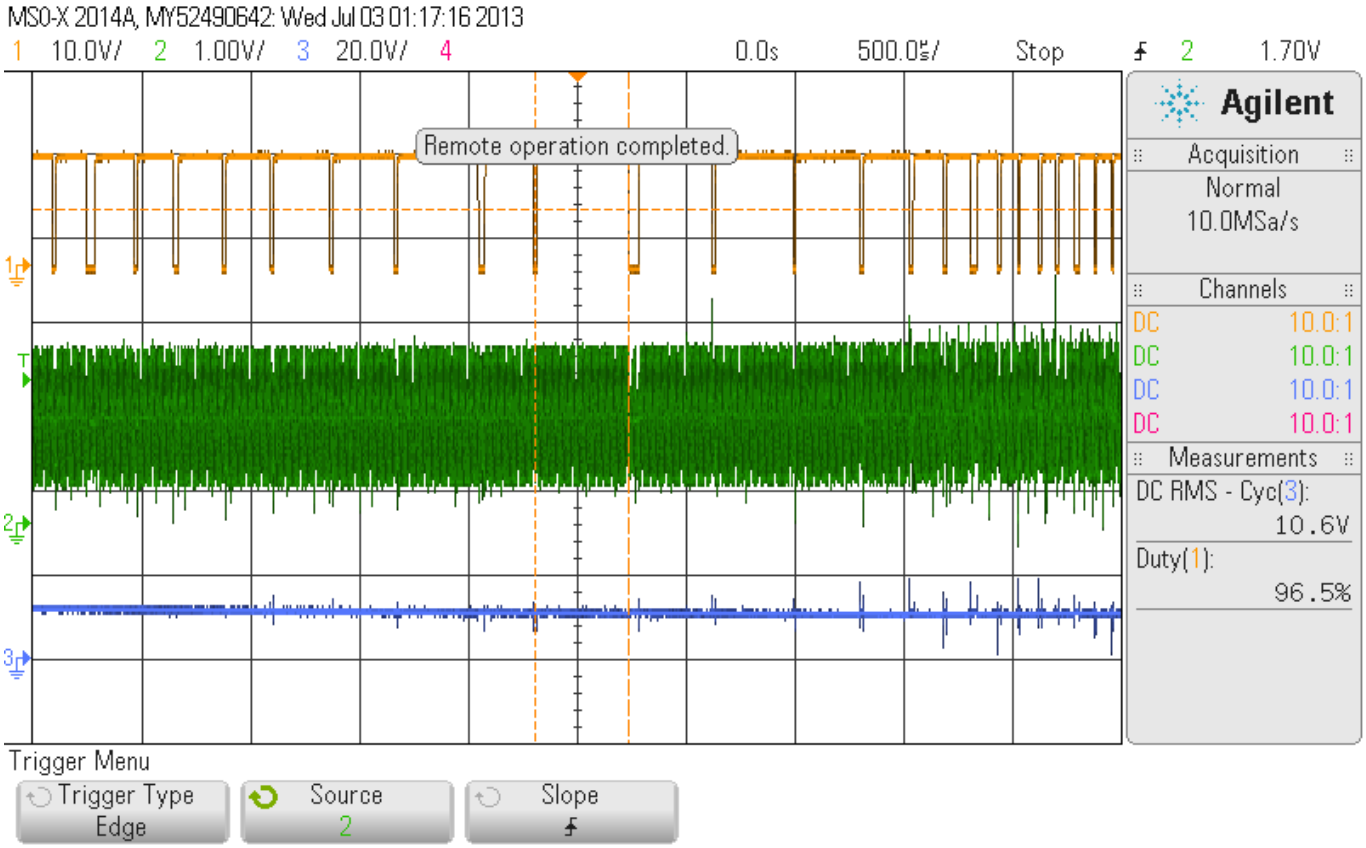


Fig 46 . PI Output Output Voltage Duty Cycle

❖ PI Output &Output Voltage & Duty Cycle

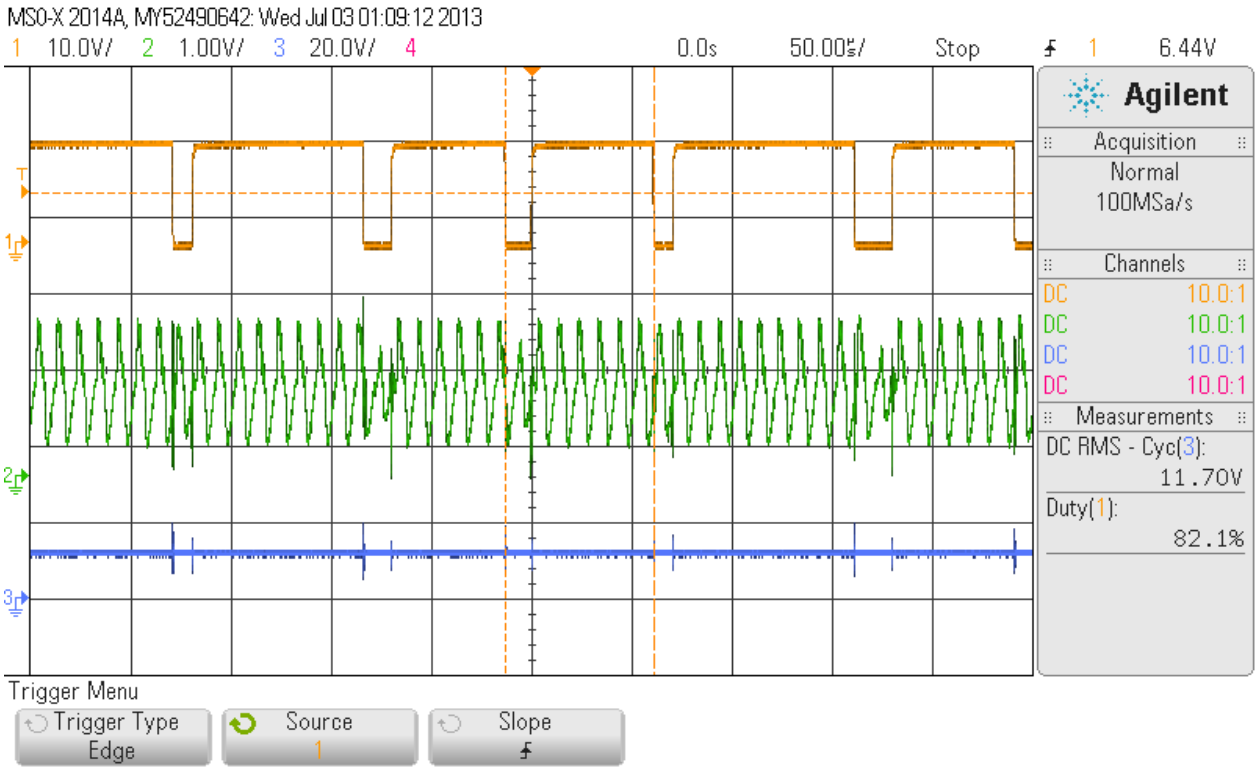


Fig 47 .PI Output Output Voltage Duty Cycle

❖ Control Stage

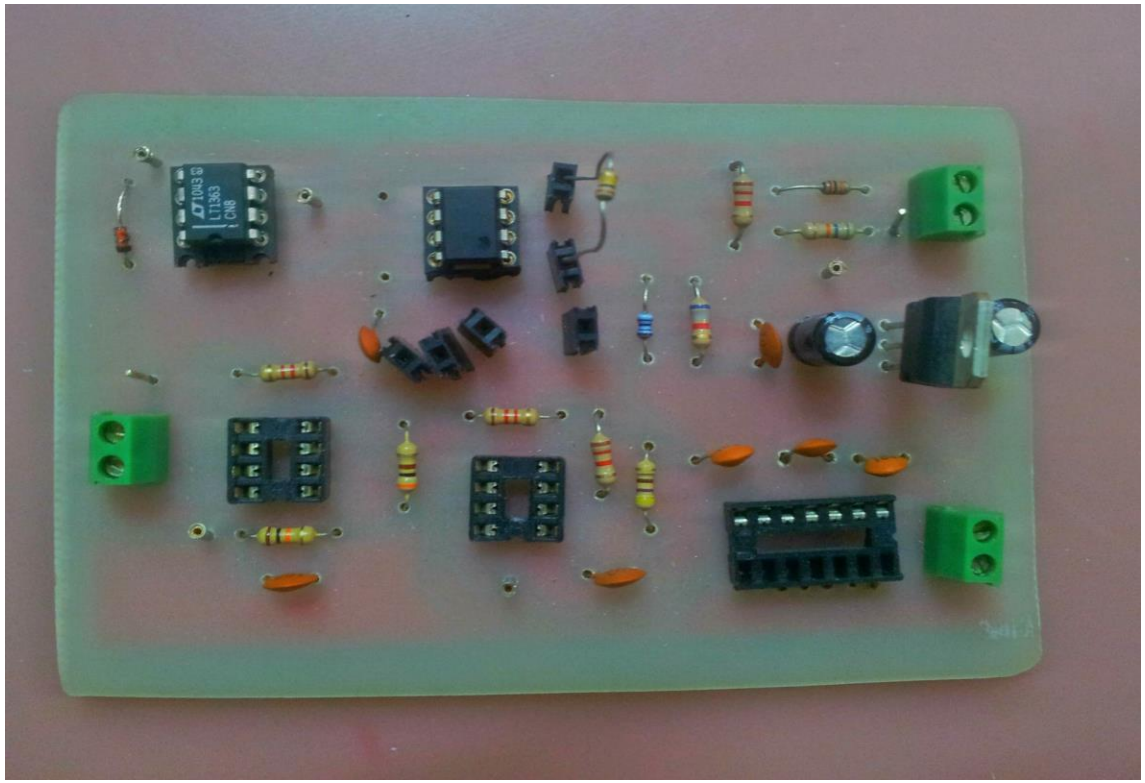


Fig 48. Control Stage

❖ PWM Output

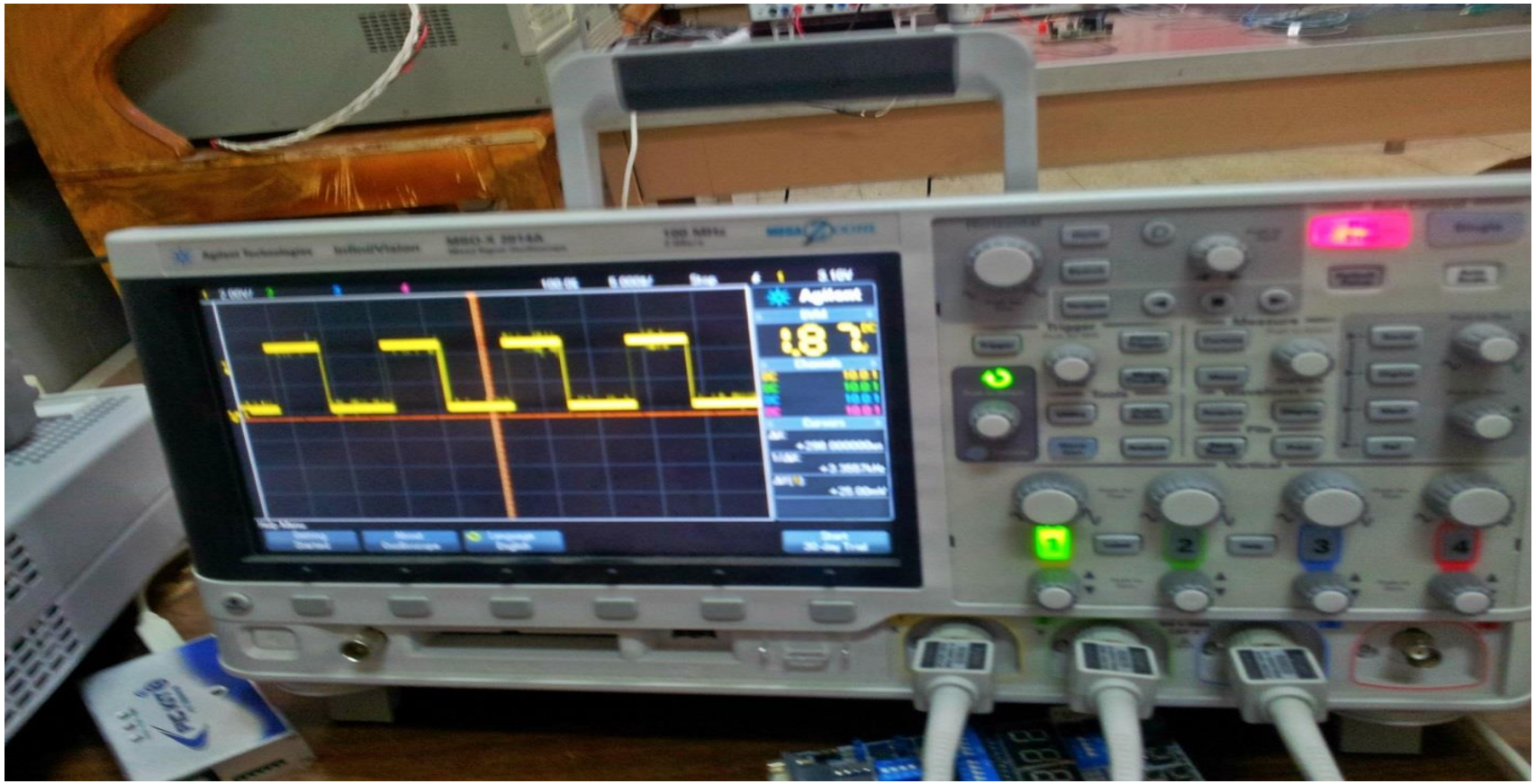


Fig 49. PWM Output

❖ PWM Output & Saw tooth Generator Output

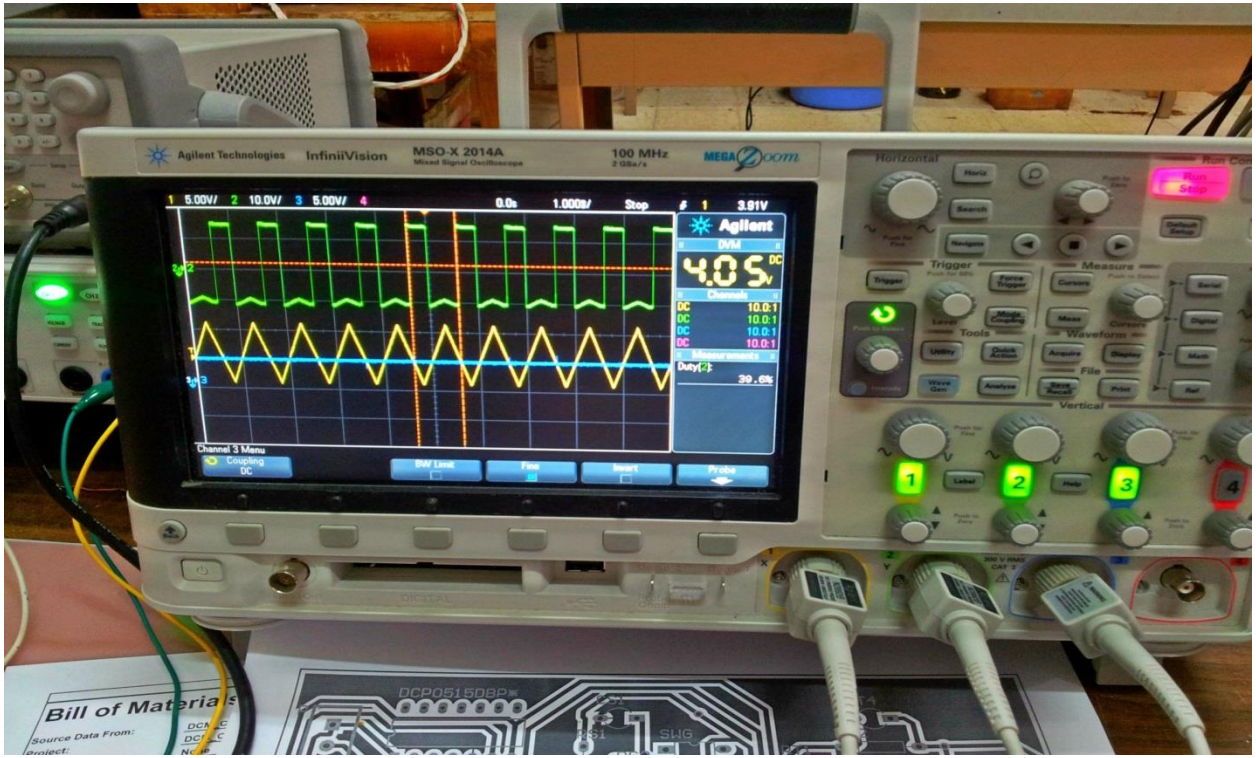


Fig 50 .PWM Output & Saw tooth Generator Output

❖ Practical Test

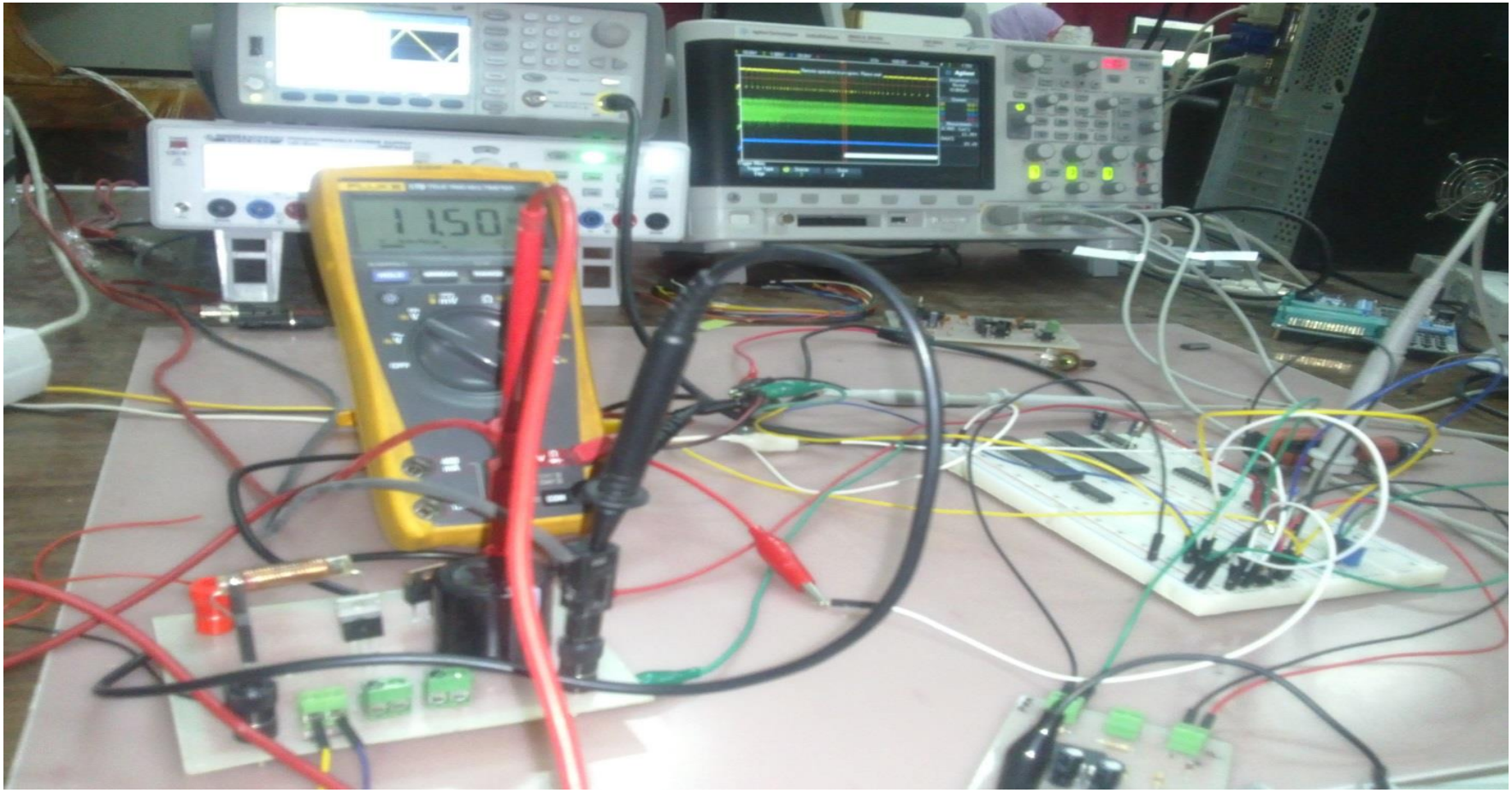


Fig 51.Practical Test

END

Thank You