UROP PROJECT

SRM UNIVERSITY 2024-25

BANDGAP REFERENCE CIRCUIT

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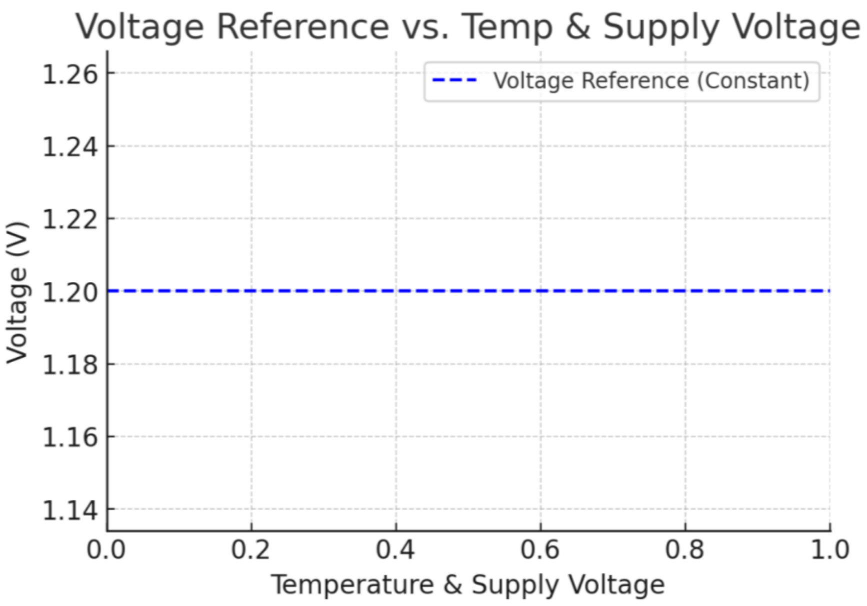
Problem Statement:

Designing Bandgap Reference Circuit

Literature Review

Bandgap Reference Circuit:

A **bandgap reference** is a circuit that generates a stable voltage reference independent of variations in power supply voltage, temperature, and transistor properties. The principle behind this circuit is based on the thermal voltage dependency of bipolar junction transistors (BJTs).



PTAT (Proportional to Absolute Temperature):

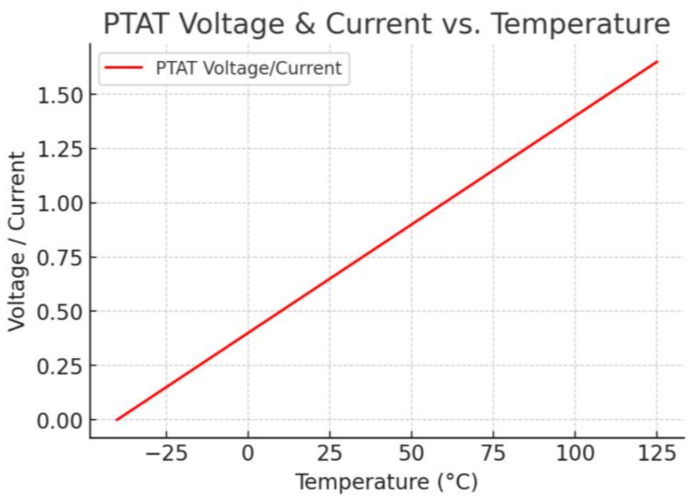
PTAT voltage or current increases **linearly** with temperature. It is derived from the difference in base-emitter voltages of two BJTs operating at different current densities.

Applications:

•Temperature sensors

•Biasing circuits in analog ICs

•Compensation techniques in voltage references

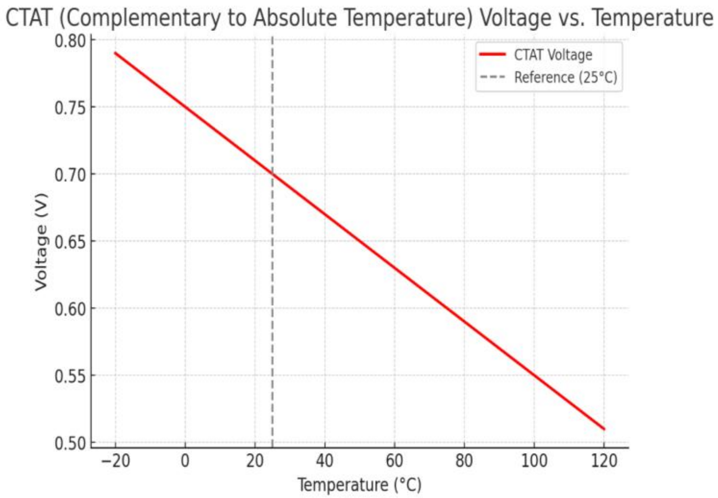


Complementary to Absolute Temperature (CTAT) Voltage:

CTAT voltage refers to a voltage that **decreases as temperature increases**. It is the opposite of PTAT (Proportional to Absolute Temperature) voltage.

Application:

1.Bandgap Reference Circuits.
2.Temperature Compensation.
3.Biasing Circuits.
4.Power Management Ics.



WORKING PRINCIPLE AND BLOCK DIAGRAM:

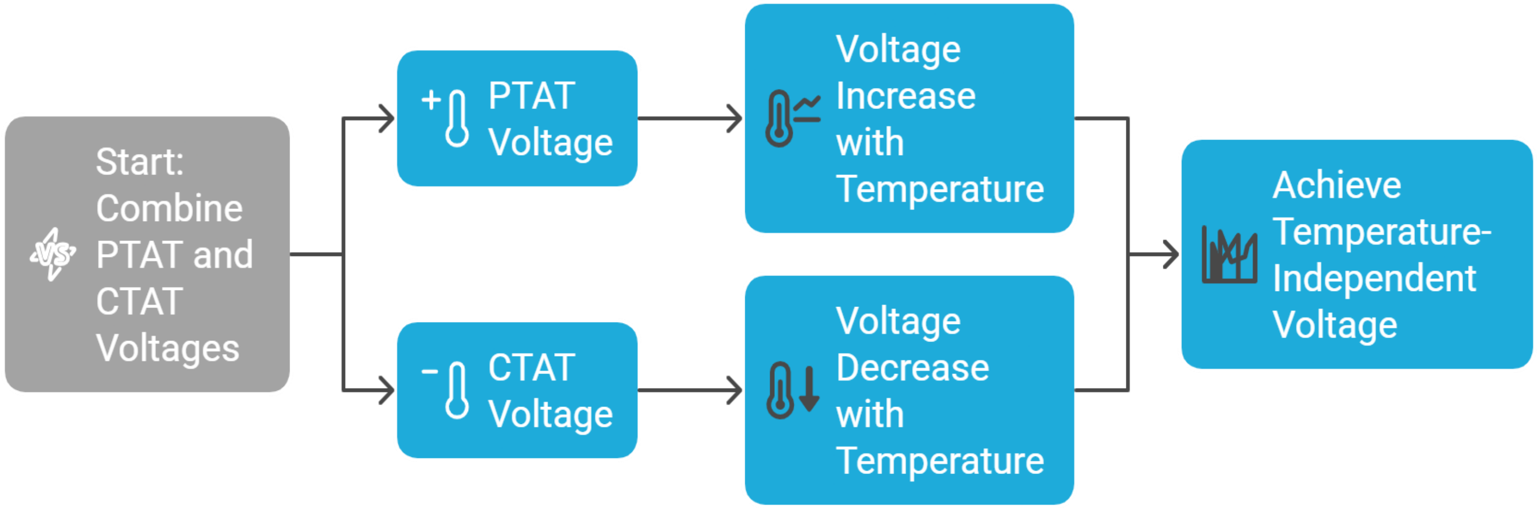
A bandgap reference circuit typically combines two voltage sources:

1. **PTAT (Proportional to Absolute Temperature) Voltage** – This voltage increases with temperature.
2. **CTAT (Complementary to Absolute Temperature) Voltage** – This voltage decreases with temperature.

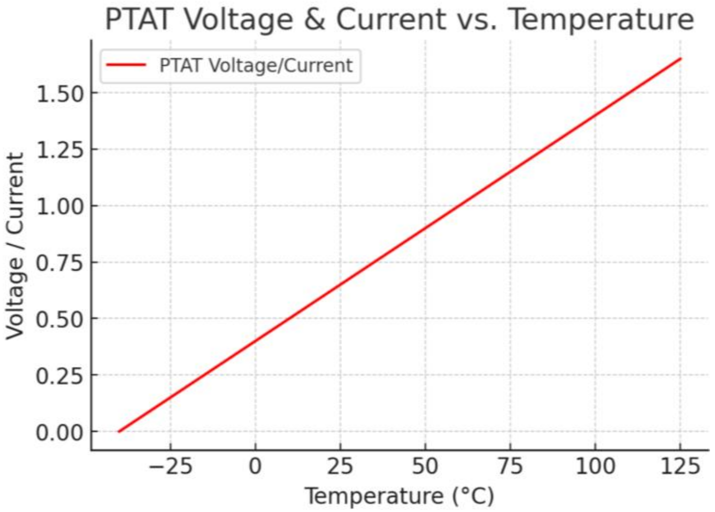
By adding PTAT and CTAT voltages, a nearly **temperature-independent voltage** is achieved.

Addition of PTAT and CTAT => $\alpha 1PTAT+\alpha 2CTAT=$Constant Voltage

Bandgap Reference Circuit Process



Addition of PTAT and CTAT => α1PTAT+α2CTAT=Constant Voltage



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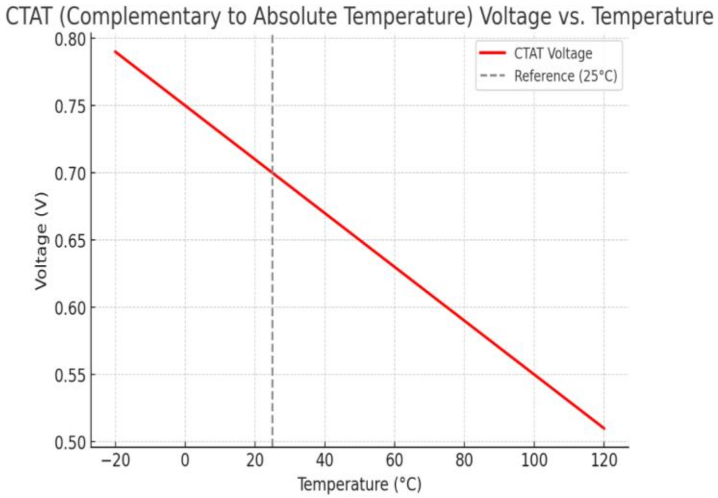

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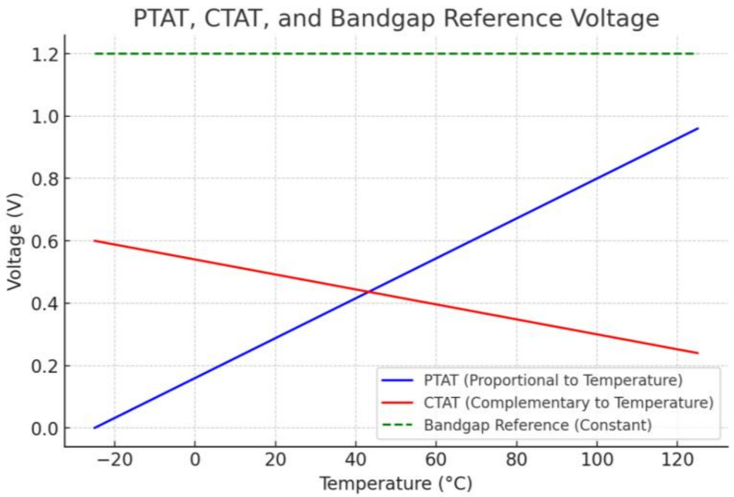
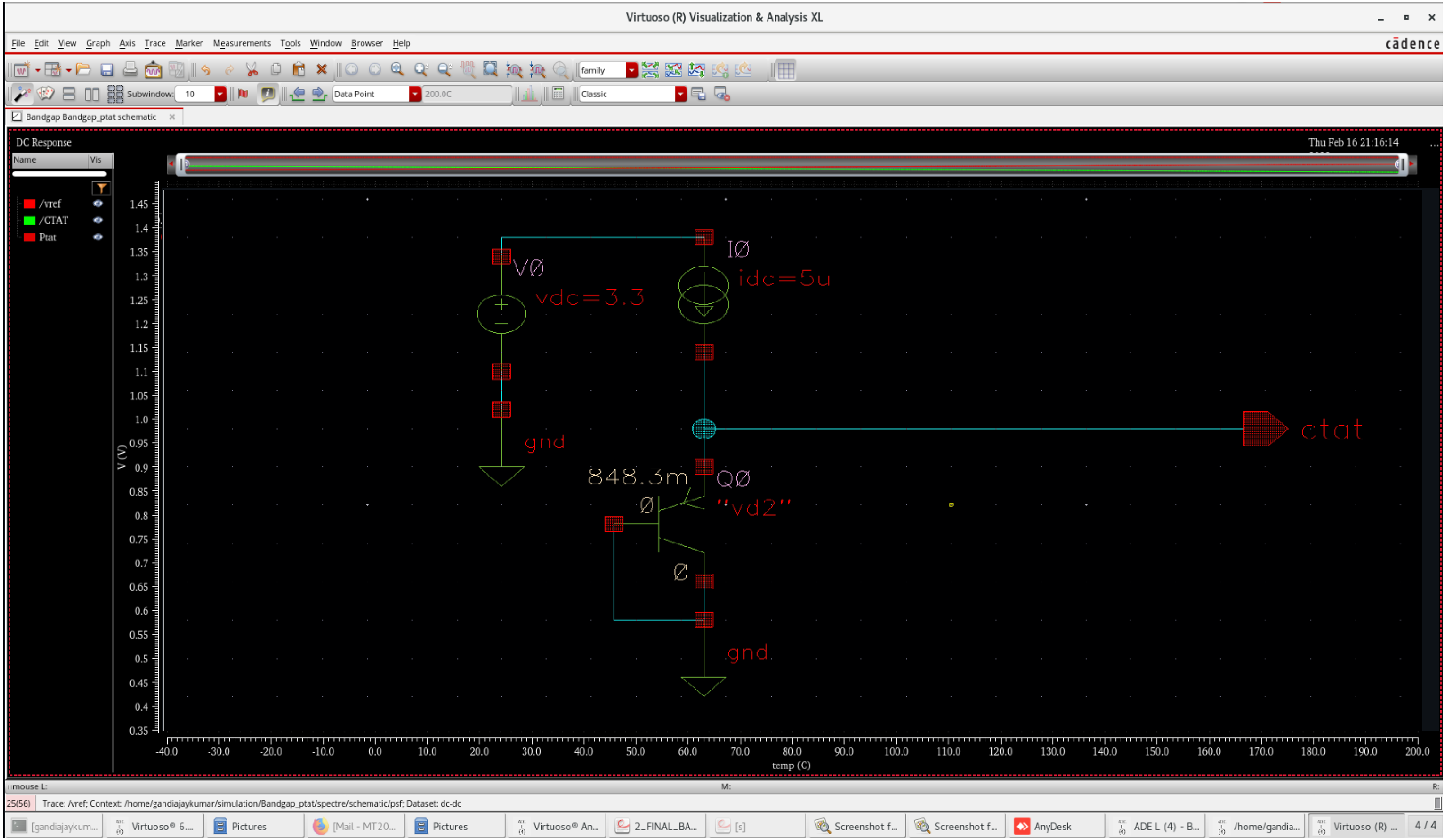
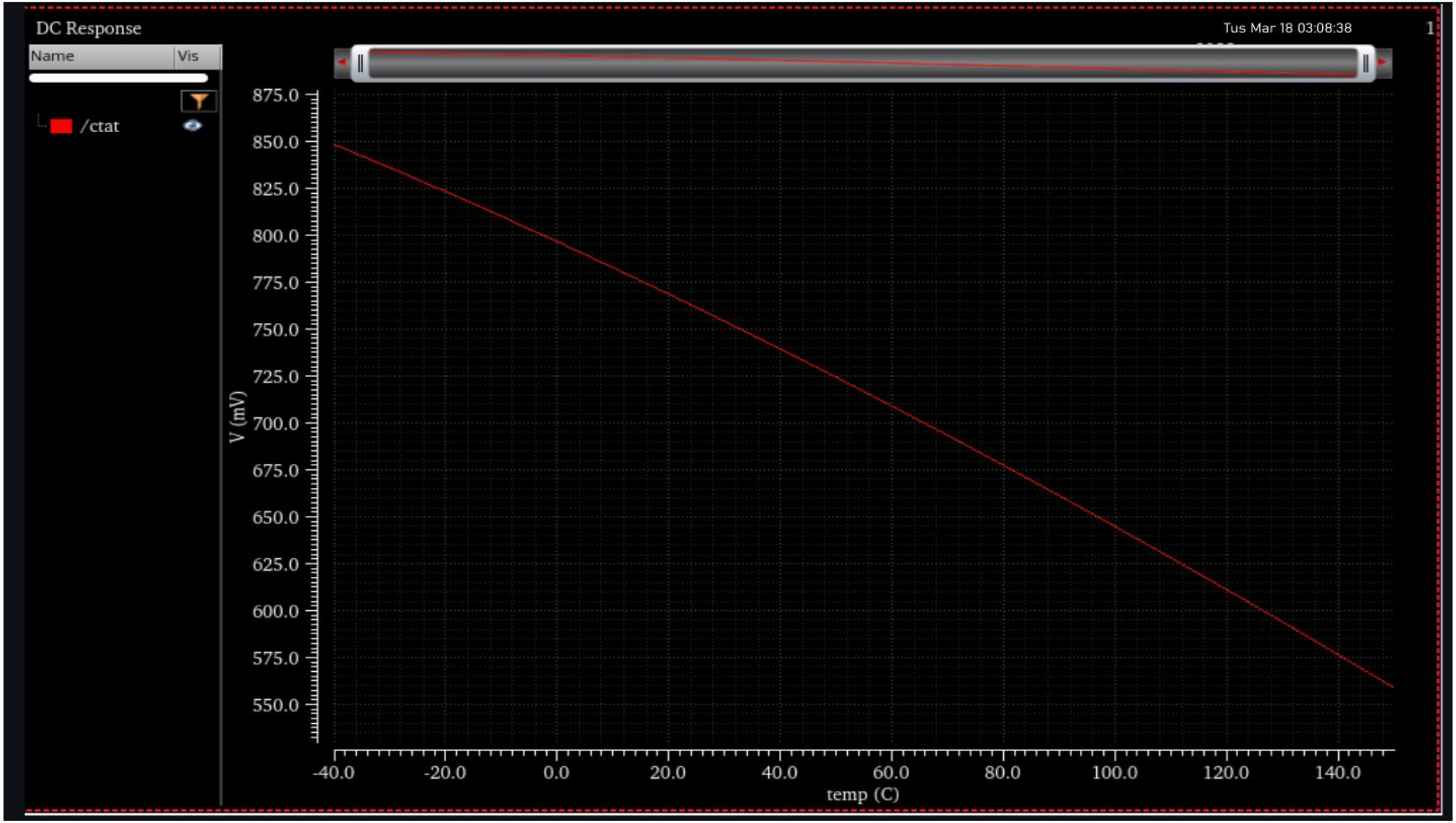


Schematic Analysis Of CTAT




DC Response
Tus Mar 18 03:08:38
Name
Vis
/ctat
V (mV)
875.0
850.0
825.0
800.0
775.0
750.0
725.0
700.0
675.0
650.0
625.0
600.0
575.0
550.0
-40.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
temp (C)

References

- https://www.youtube.com/watch?v=aynJSMErq4g&list=PLK2eyR1C9gjp5tk5j7eTYU_Th4IL_H83T&index=3
- https://www.researchgate.net/publication/382569345_Research_Progress_of_Bandgap_Reference_Circuit

Research Progress of Bandgap Reference Circuit

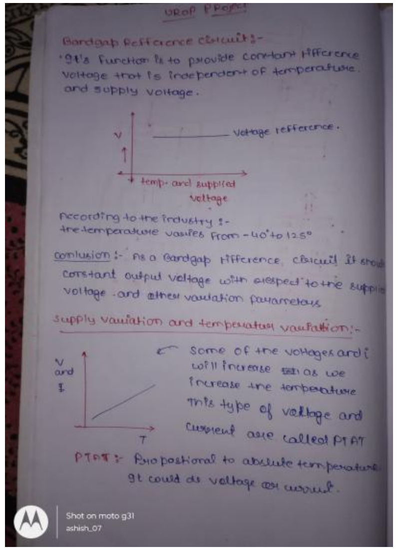
Abstract. As an important part of integrated circuit design, bandgap reference circuit is widely used in various chips, among which ADC (analog-to-digital converter) and DAC(digital-to-analog converter) are typical examples. This paper introduces the bandgap reference circuit and its working principle in detail, and then systematically combs and introduces a variety of bandgap reference circuits. A conventional bandgap reference circuit consists of an op-amp, two bipolar transistors and multiple resistors; The CMOS bandgap reference circuit uses the common-source common-gate current mirror to provide the bias current to reduce the power consumption and the channel length modulation effect so that the circuit can work at a lower supply voltage. A bandgap reference circuit using PTAT (proportional to absolute temperature) current to generate reference voltages with different temperature coefficients can produce a simpler circuit structure than the traditional bandgap reference circuit. By summarizing and comparing these bandgap reference circuits, the latest trends and technical trends in this field are presented, providing guidance and inspiration for future research work.

Keywords: PTAT; bandgap reference circuit; cascade current mirror.

Future Work:

- Schematic and Design Analysis of the PTAT.
- Combining the ptat and ctat to get the full band gap circuit.

Notes:


Bandgap Refference circuits:-
It's function is to provide constant difference voltage that is independent of temperature and supply voltage.

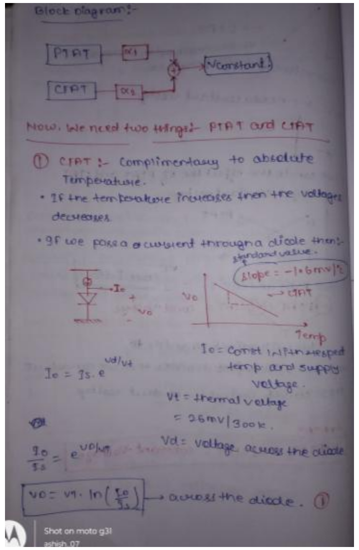
According to the industry :- the temperature varies from −40° to 125°

Conclusion :- As a bandgap difference circuit it should constant output voltage with respect to the supply voltage and other variation parameters.

Supply variation and temperature variation:-

Some of the voltages and I will increase as we increase the temperature. This type of voltage and current are called PTAT.

PTAT :- Proportional to absolute temperature. It could be voltage or current.


Block diagram:-

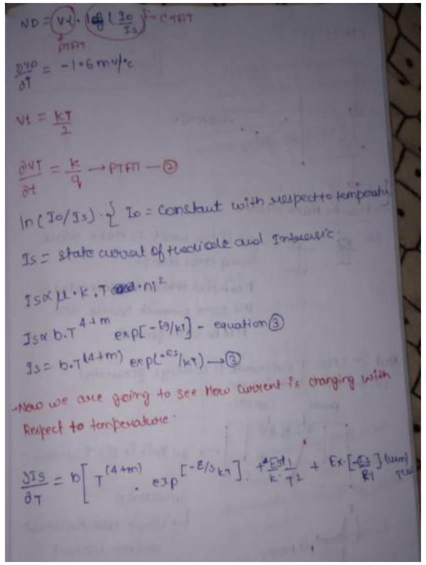
Now, we need two things PTAT and CTAT

① CTAT :- Complimentary to absolute temperature.
• If the temperature increases then the voltage decreases.
• If we pass a current through a diode then:-

$I_D = I_S \cdot e^{V_d/V_t}$

I_D = const with respect temp and supply voltage.
V_t = thermal voltage = 26mV/300K.
V_d = voltage across the diode.

$\boxed{V_D = V_t \cdot \ln\left(\frac{I_D}{I_S}\right)}$ → across the diode. ①


$\frac{\partial V_D}{\partial T} = -1.6\,mV/^\circ C$

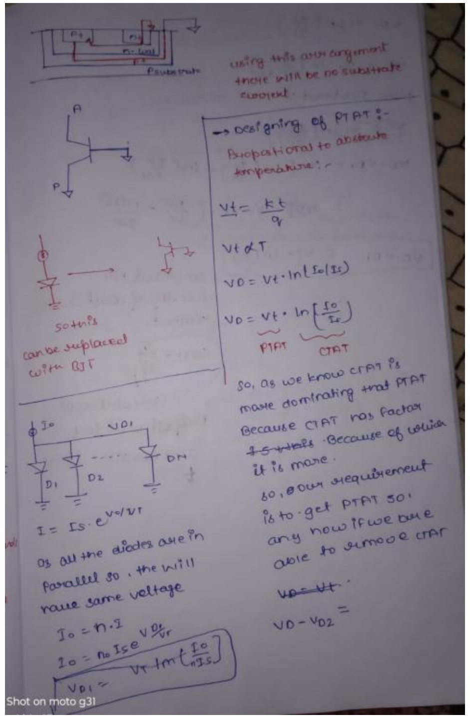
$V_t = \frac{kT}{q}$

$\frac{\partial V_T}{\partial t} = \frac{k}{q}$ → PTAT — ②

$\ln(I_D/I_S)$: I_D = constant with respect to temperature

I_S = state current of the diode and intrinsic

Now we are going to see how current is changing with respect to temperature.


Using this arrangement there will be no substrate current.

→ Designing of PTAT :- Proportional to absolute temperature :-

$V_t = \frac{kt}{q}$

$V_t \propto T$

$V_D = V_t \cdot \ln(I_D/I_S)$

Can be replaced with BJT

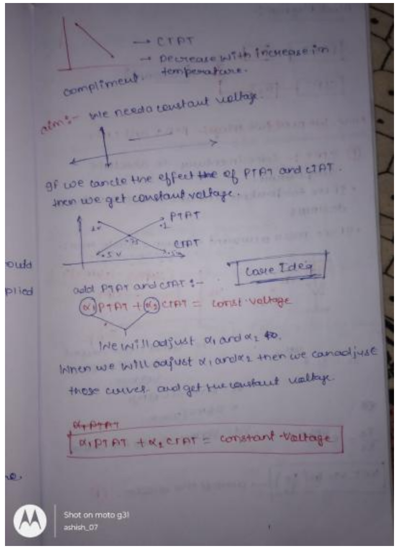
So, as we know CTAT is more dominating that PTAT because CTAT has factor. Because of which it is more. So, our requirement is to get PTAT so, if we are any how able to remove CTAT.

$I = I_S \cdot e^{V_D/V_T}$

As all the diodes are in parallel so, they will have same voltage

$I_O = n \cdot I$

$V_D - V_{D2} =$


→ CTAT
→ Decrease with increase in temperature.

aim :- We need a constant voltage.

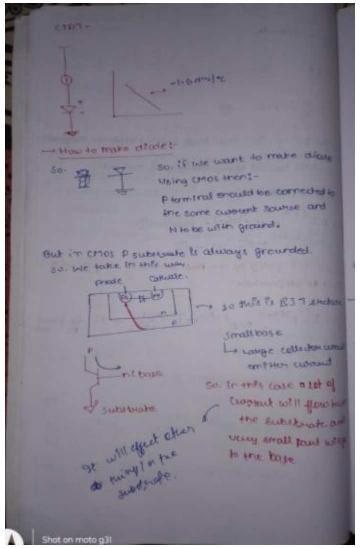
If we cancle the effect the of PTAT and CTAT then we get constant voltage.

Core Idea

add PTAT and CTAT :-
α_1 PTAT + α_2 CTAT = const voltage

We will adjust α_1 and α_2 to.
When we will adjust α_1 and α_2 then we can adjust these curves and get the constant voltage.

$\boxed{\alpha_1 PTAT + \alpha_2 CTAT = \text{constant Voltage}}$


How to make diode:-

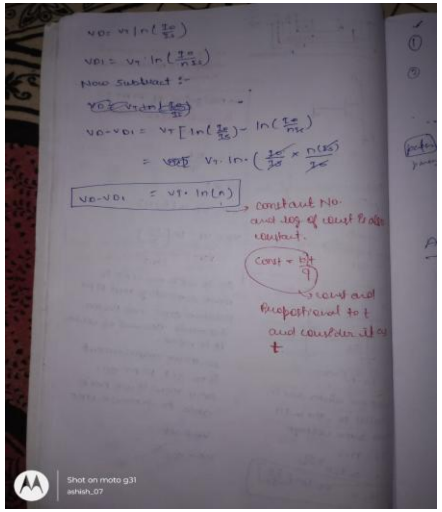
So, if we want to make diode using CMOS then:- P terminal should be connected to the same current source and N to be with ground.

But in CMOS P substrate is always grounded.

Small base
large collector and emitter current

So, in this case a lot of current will flow to the substrate and very small part will go to the base

It will effect other devices in the substrate.


$V_D = V_t \ln\left(\frac{I_O}{I_S}\right)$

$V_{D1} = V_t \cdot \ln\left(\frac{I_O}{nI_S}\right)$

Now Substitute :-

$V_D - V_{D1} = V_t\left[\ln\left(\frac{I_O}{I_S}\right) - \ln\left(\frac{I_O}{nI_S}\right)\right]$

$\boxed{V_D - V_{D1} = V_t \cdot \ln(n)}$

→ constant No. and log of const is also constant.

Const = $\frac{k}{q}$ is const and Proportional to t