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COIMBATORE-641 035, TAMIL NADU

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Course Name: 23ECT203 LINEAR INTEGRATED CIRCUITS

II YEAR/VI SEMESTER

UNIT III –ANALOG MULTIPLIER AND PLLR

Topic :Analog Multiplier using Emitter Coupled Transistor Pair - Gilbert Multiplier cell

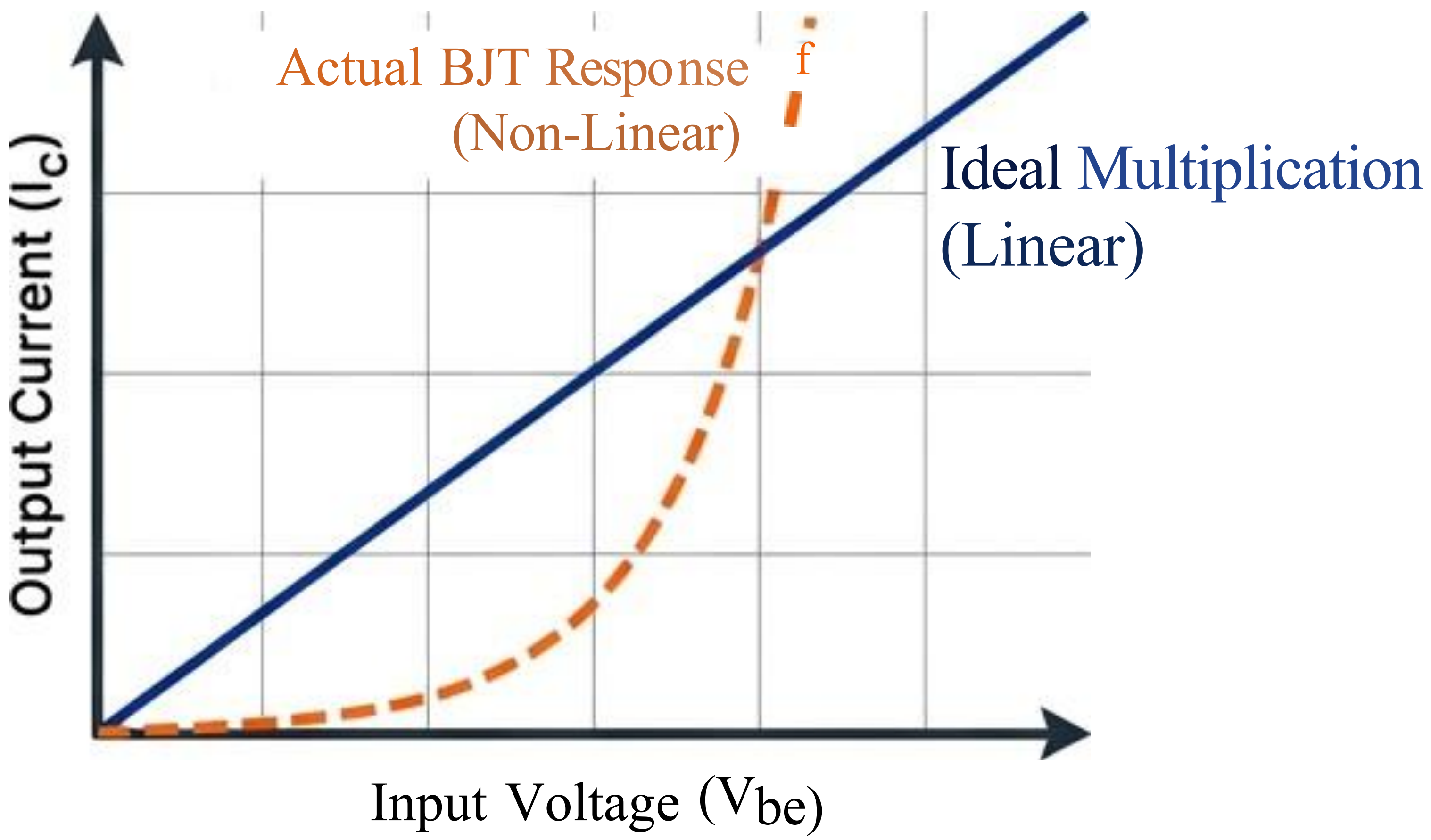
Design Thinking Stage 1: Empathize

The User Need in Communication Systems

- The Need: Precise control over signal amplitude and frequency mixing.
- The Context: Simple resistive or diode circuits cause signal distortion.
- The Goal: A 'Perfect Mixer' capable of handling positive and negative signals simultaneously (Four-Quadrant Operation).

Design Thinking Stage 2: Define

The Problem of Non-Linearity



Physics Problem: BJTs have an exponential V-I characteristic.

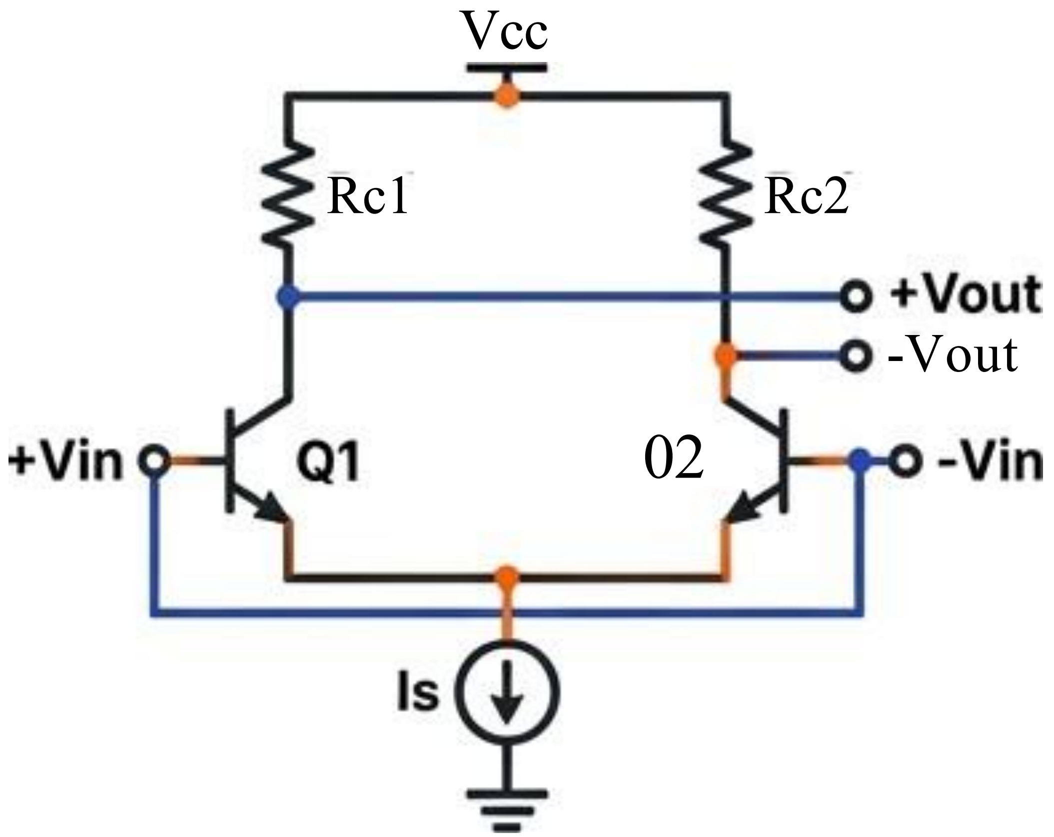
Equation: Ic = Is • e^(Vbe/Vt))

Challenge: How to achieve linear multiplication using non-linear devices?

Requirement: Must operate in all 4 quadrants (Positive/Negative inputs).

Design Thinking Stage **3:** Ideate

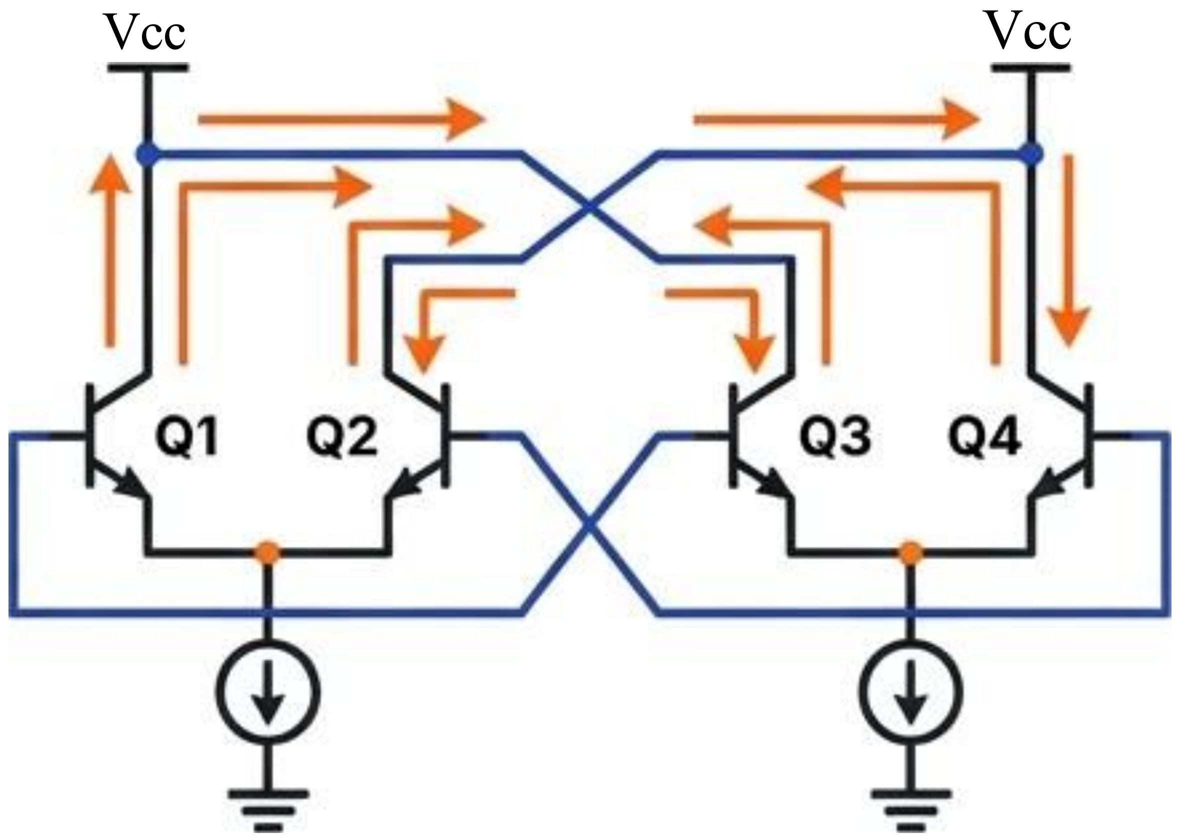
Ideation A



Standard Differential Pair Good

for gain, but limited linearity.

Ideation B

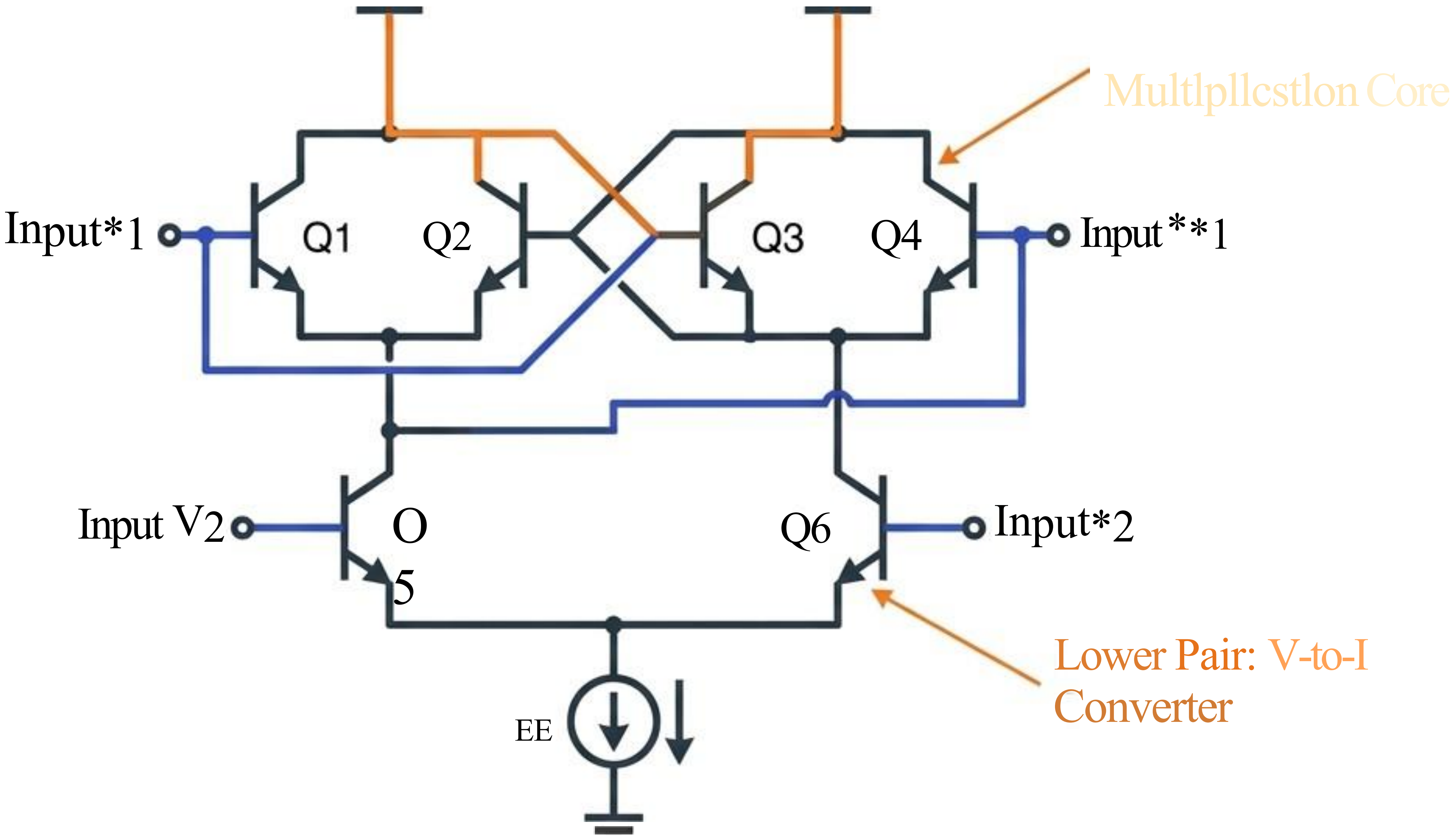


Cross-Coupled Architecture

The Breakthrough: Cancellation of non-linear terms.

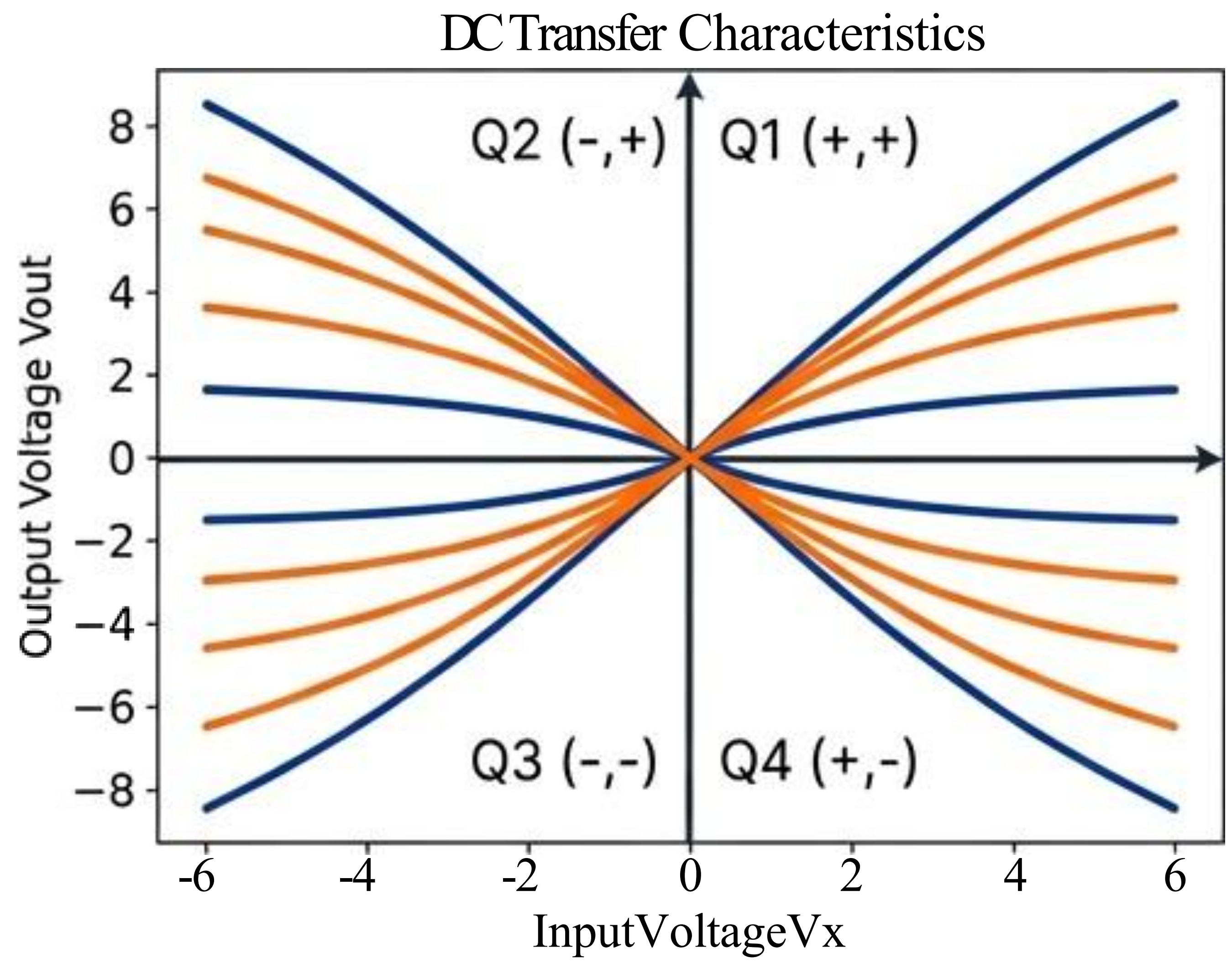
- Concept: Variable Transconductance.
- Solution: Cross-coupling two pairs allows the non-linear exponential terms to subtract and cancel each other.
- Mechanism: Current Steering Logic.

Design Thinking Stage 4: Prototype



Design Thinking Stage 5: Test

Validating Four-Quadrant Operation



- Verification: The circuit multiplies successfully for both positive and negative polarities of inputs.
- Linearity Check: Response is linear within the range of Thermal Voltage (Vt) (in JetBrains Mono).
- Result: The cross-coupled structure effectively linearizes the hyperbolic tangent (tanh) response (in JetBrains Mono).

Key Parameters

Scale Factor (K)

The proportionality constant. Typical value: 1/10 V^{-1}.

$$Vout = \frac{Vx \cdot Vy}{10}$$

Differential Gain

High ability to reject common-mode noise.

Linearity & Range

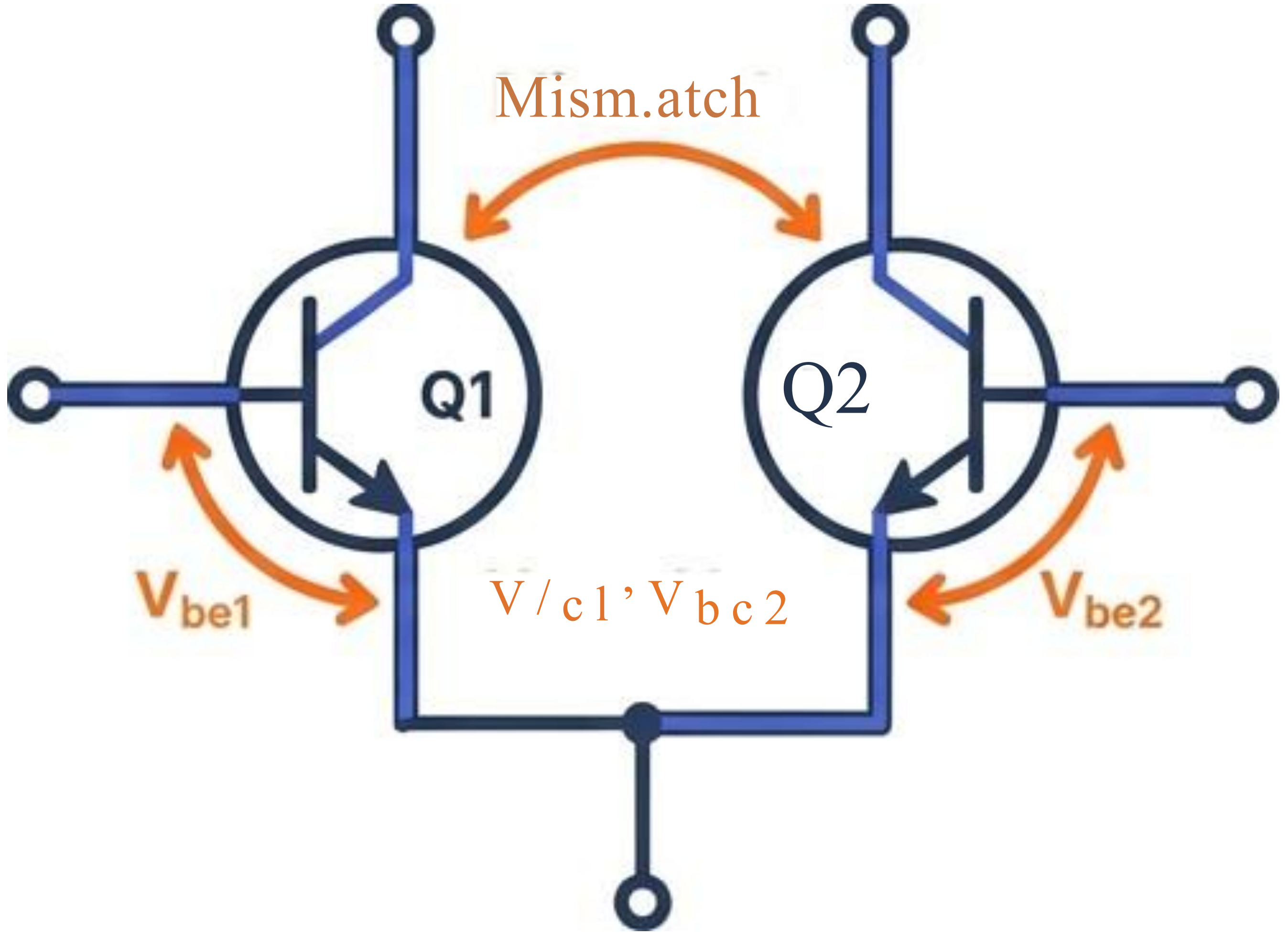
Percentage deviation from ideal product.

Dynamic range limited by Vcc and bias currents.

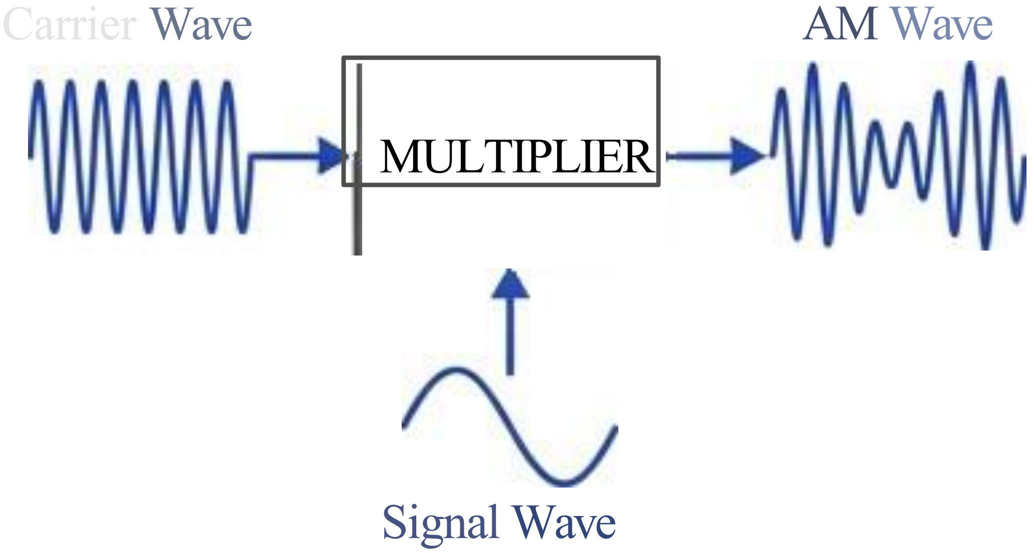
Practical Limitations

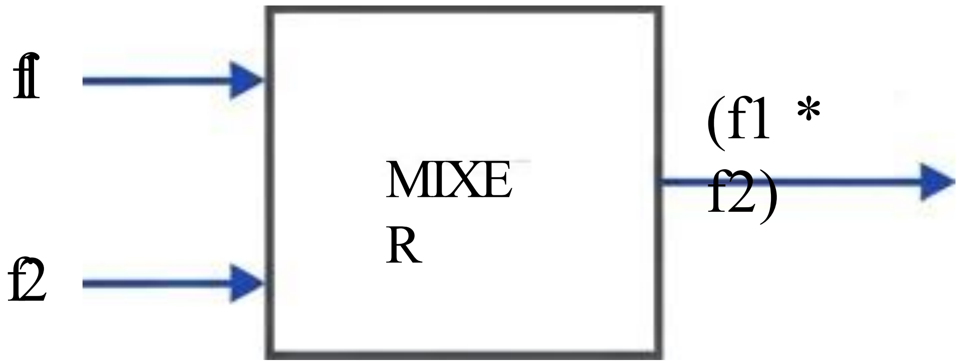
- Device Mismatch: Slight manufacturing differences in Transistor Beta or Vbe cause DC Offset Errors (Output is not zero when input is zero).
- Temperature Drift: Transconductance (gm) depends on Thermal Voltage (Vt = kT/q) (rendered in 3etBrains hono).

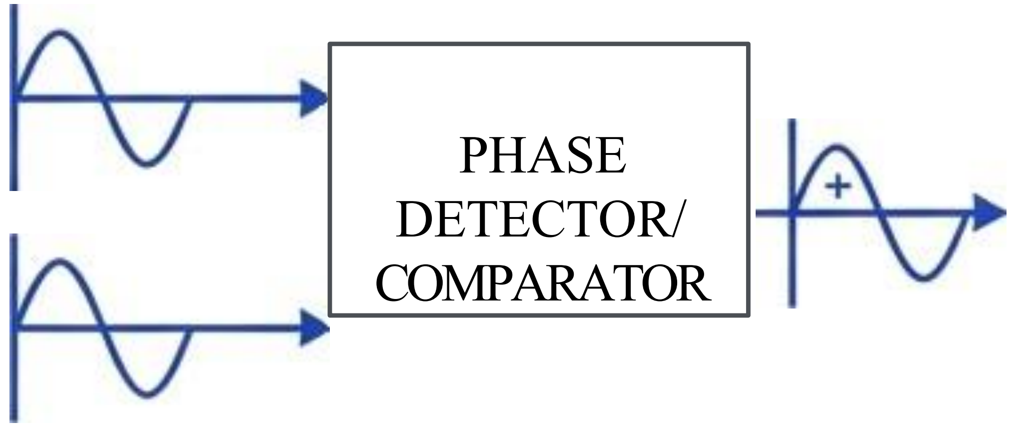
  —As Temperature rises -> Gain changes.
- Mitigation: External trimming resistors and pre-distortion circuits are used in commercial ICs (e.g., MC1496).



Real-World Applications





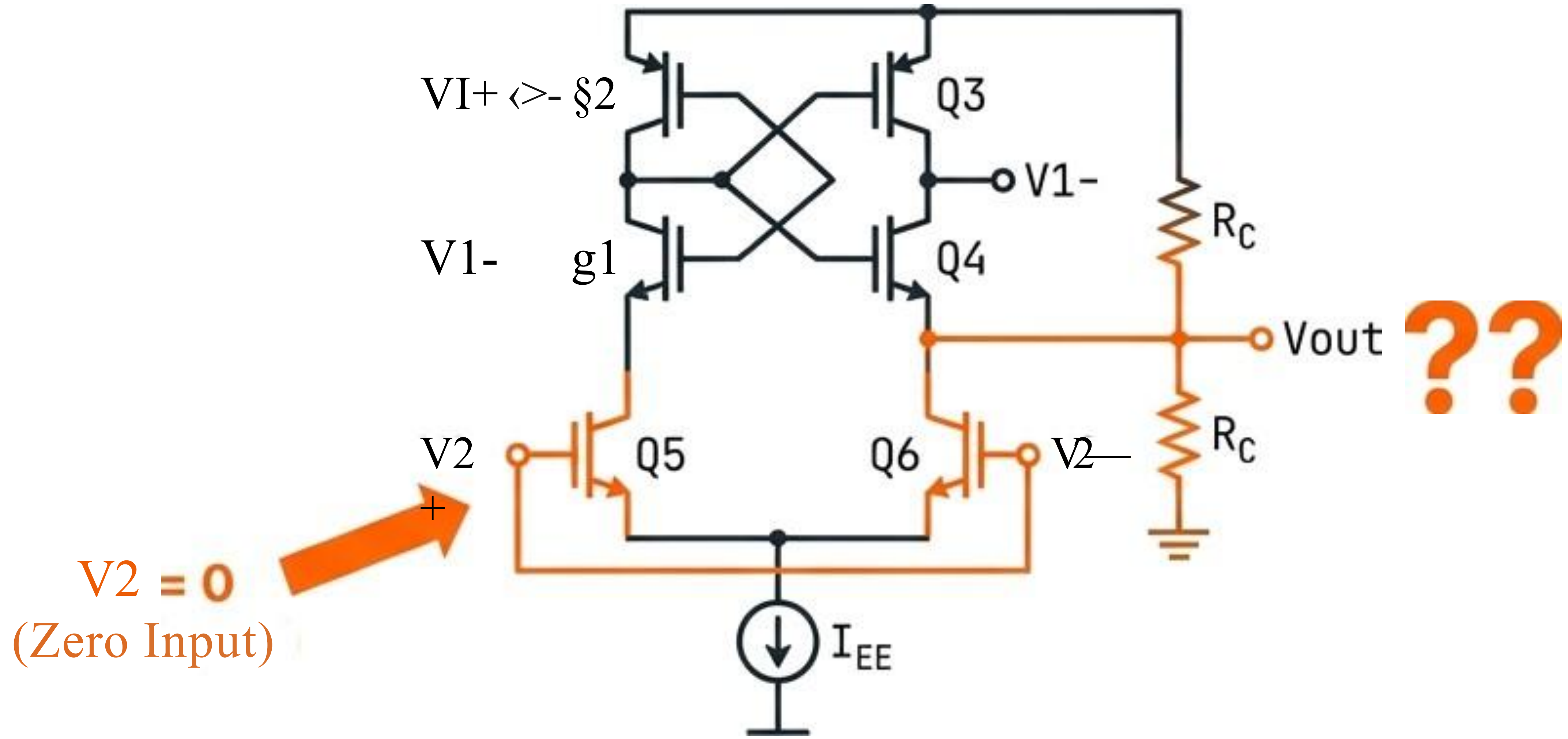


Amplitude Modulation (AM) & DSB-SC.

RF Communication Receivers (Superheterodyne).

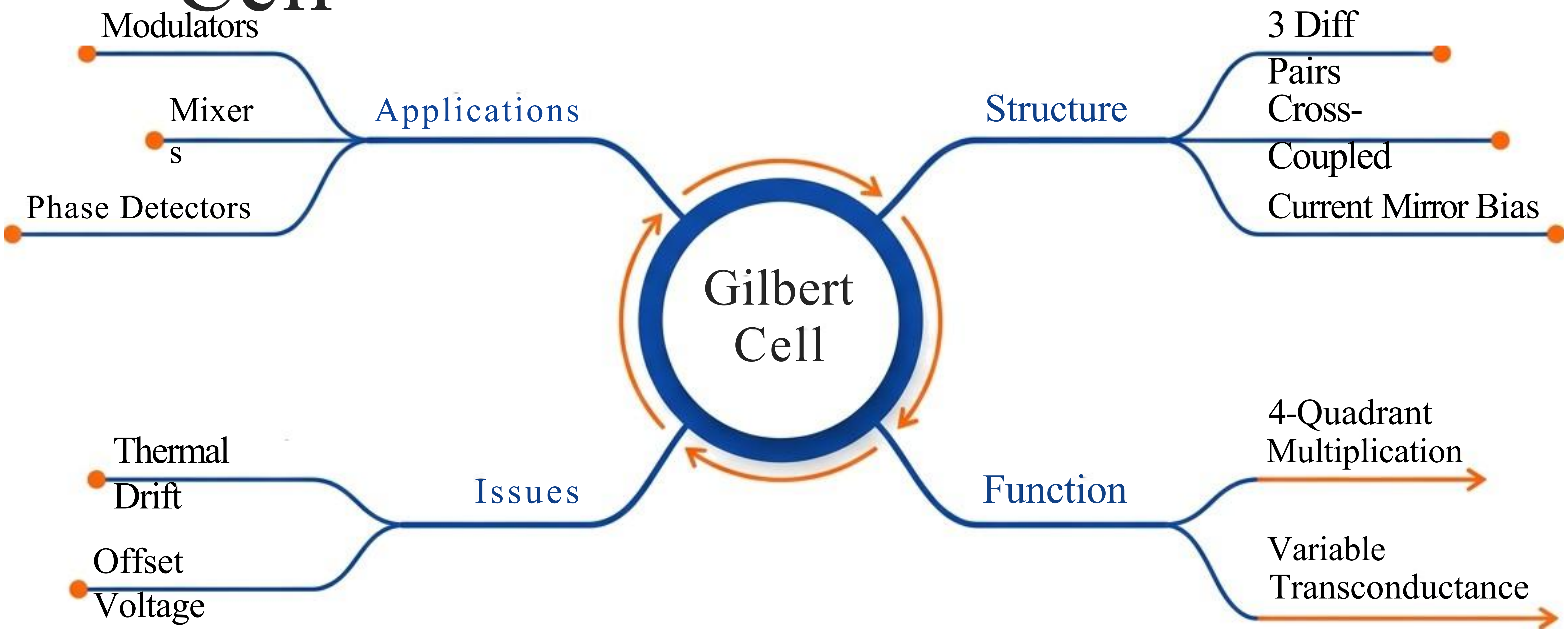
Phase Locked Loops (PLL) for signal synchronization.

Class Activity: Circuit Analysis



Challenge: Consider the Gilbert Cell Schematic.
Condition: If the differential input to the bottom pair (V2) is ZERO...
Question: What is the AC output voltage, regardless of what Input V1 is doing?

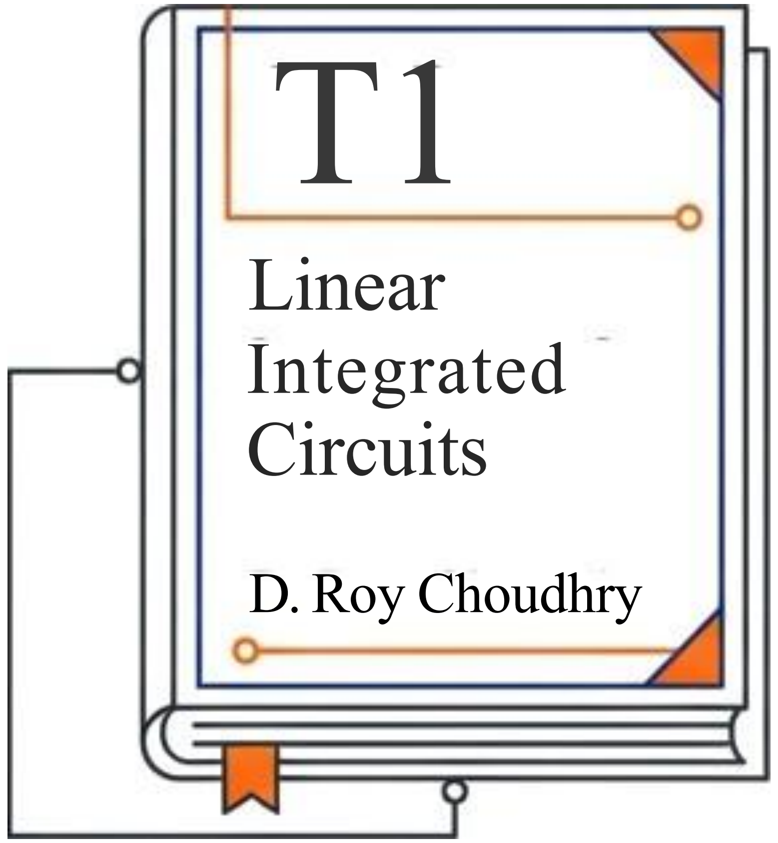
Mind Map: Gilbert Multiplier Cell

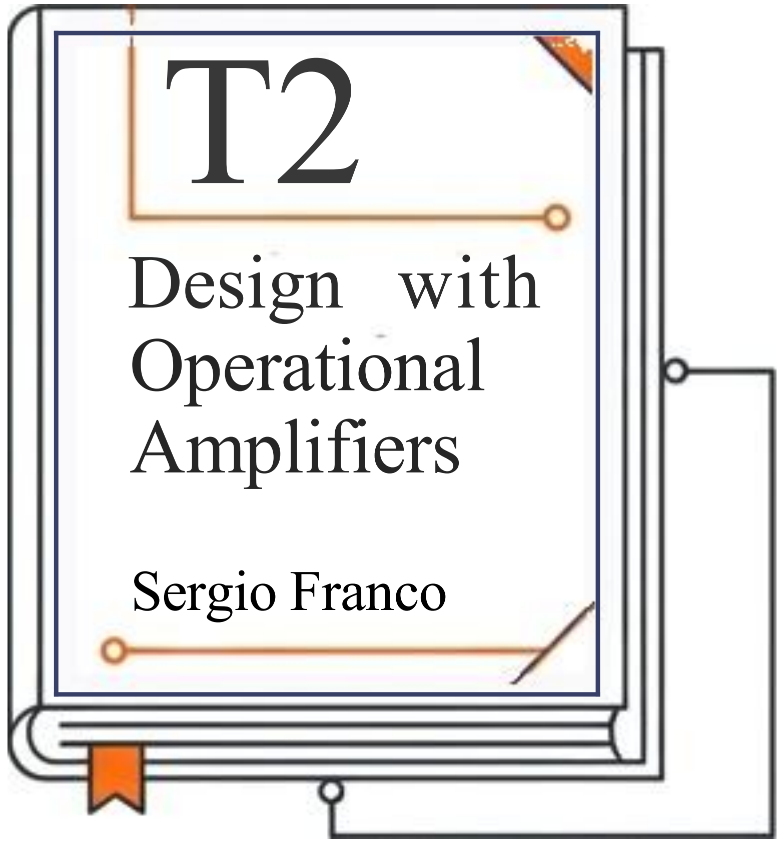


Assessment

1. Why is 'cross-coupling' used in the Gilbert Cell?
   (Ans: To cancel non-linear terms)
2. What is the typical value of the scale factor K?
   (Ans: 1/10)
3. Name one practical limitation of this circuit.
   (Ans: Temperature drift or Offset)
4. In which quadrant(s) does the Gilbert cell operate?
   (Ans: All four)

References





T1: D. Roy Choudhry, Shail Jain, 'Linear integrated Circuits', New Age International Pvt. Ltd., Fifth edition 2018.

T2: Sergio Franco, 'Design with Operational Amplifiers and Analog integrated Circuits', Fourth Edition, Tata McGraw-Hill, 2014.

W1: NPTEL Course - https://nptel.ac.in/courses/108/106/108106153

Thank you