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15/ENG04/009
EEE524
ANALOG IC DESIGN AND APPLICATION
ELECT/ELECT

ANALOG MULTIPLIERS

An analog multiplier is a circuit that takes two analog inputs and produces an output proportional to their product. It is one of the commonly used techniques for performing multiplication and division within a monolithic integrated circuit.

EMITTER COUPLED PAIR AS A SIMPLE MULTIPLIER

The output currents IC1 an d IC2 are related to the differential input voltage V_1 by

$$I_{C1} = \frac{I_{EE}}{1+e^{V_1/V_T}} \text{ and } I_{C2} = \frac{I_{EE}}{1+e^{V_2/V_T}}$$

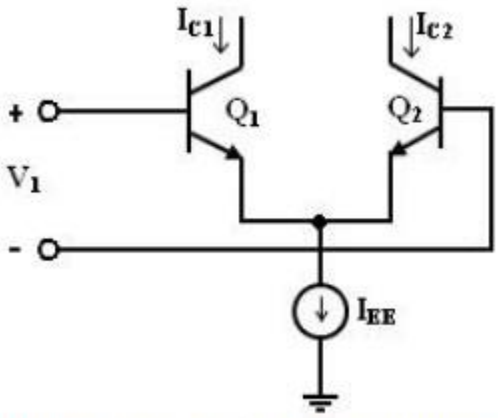


Fig.3.5 multiplier circuit using an emitter coupled pair

where V is thermal voltage and the base currents have been neglected. Combining above eqn., difference between=the two output− currents as

$$\Delta I_C = I_{C1} - I_C = \frac{I_{EE}}{1+e^{V_1/V_T}} - \frac{I_{EE}}{1+e^{V_2/V_T}} = I_{EE} \tanh(V_1/2V_T)$$

The dc transfer characteristics of the emitter – coupled pair is shown in figure. It shows that the emitter coupled pair can be used as a simple multiplier using this configuration. When the differential input voltage $V_1 << V_T$, we can appropriate as given by

$\Delta I_C = I_{EE} (V_1/2V_T)$

The current I_{EE} is the bias current for the emitter – coupled pair. If the current I_{EE} is made proportional to a second input signal V_2, then

$I_{EE} = K_0 (V_2 - V_{BE})/2V_T$

Substituting above eqn. , we get

$\Delta I_C = K_0 V_1 (V_2 - V_{BE})/2V_T$

GILBERT MULTIPLIER CELL

The Gilbert multiplier cell is a modification of the emitter coupled cell and this allows four – quadrant multiplication. Therefore, it forms the basis of most of the integrated circuit balanced Multipliers. Two cross- coupled emitter- coupled pairs in series connection with an emitter coupled pair form the structure of the Gilbert multiplier cell.

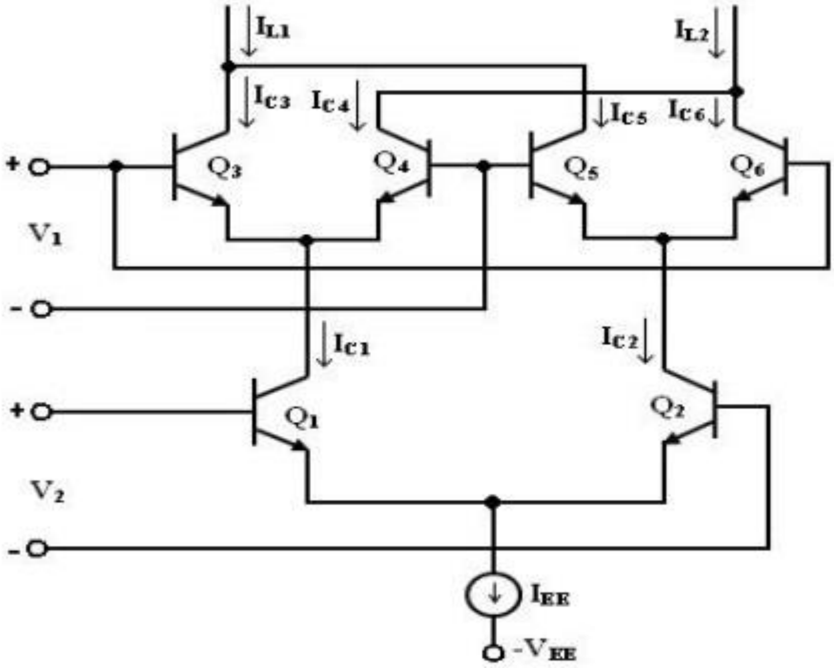
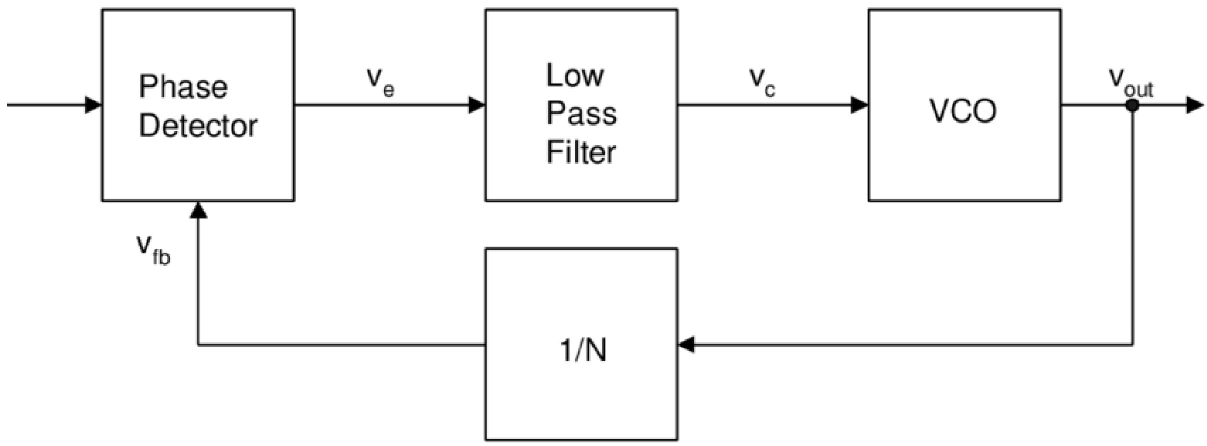


Fig. 3.8 Gilbert multiplier cell

The advantage of this circuit is the output current is an accurate multiplication of the (differential) base currents of both inputs. As a mixer, its balanced operation cancels out many unwanted mixing products, resulting in a "cleaner" output.

PHASE LOCKED LOOP CIRCUITS(PLL)

A PLL is a feedback system that includes a VCO, phase detector, and low pass filter within its loop. Its purpose is to force the VCO to replicate and track the frequency and phase at the input when in lock. The PLL is a control system allowing one oscillator to track with another.



COMPONENTS OF PLL

- **Phase detector**: Compares the phase at each input and generates an error signal, $v_e(t)$, proportional to the phase difference between the two inputs. K_D is the gain of the phase detector (V/rad).
- **Low Pass Filter:** The primary function is to determine loop dynamics, also called stability. This is how the loop responds to disturbances, such as changes in the reference frequency, changes of the feedback divider, or at start up. The second common consideration is limiting the amount of reference frequency energy (ripple) appearing at the phase detector output that is then applied to the VCO control input.
- **VCO:** In PLL applications, the VCO is treated as a linear, time-invariant system. Excess phase of the VCO is the system output. The VCO oscillates at an angular frequency, ω_{out}. Its frequency is set to a nominal ω_0 when the control voltage is zero. Frequency is assumed to be linearly

proportional to the control voltage with a gain coefficient K_O or K_{VCO} (rad/s/v).

<u>APPLICATIONS OF PLL</u>

- Clock generation
- Frequency synthesizer
- Clock recovery in a serial data link