

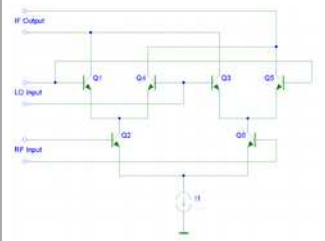
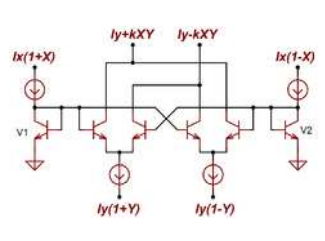
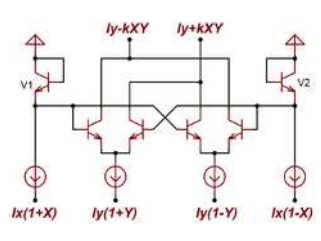
Gilbert cell

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In electronics, the **Gilbert cell** is an elaborated cascode circuit used as an analog multiplier and frequency mixer. It was invented by Howard Jones in 1963, "Dual output synchronous detector utilizing transistorized differential amplifiers", patent US3241078A, 03/15/1966, but usually attributed to Barrie Gilbert (before joining Analog Devices) in 1968.^[1]

The properties of the circuit is that the output current is a 4 quadrant multiplication of the differential base voltages of the LO and RF inputs.

Function

		
Howard Jones, 1963	Gilbert, 1968 (beta independent)	Gilbert, later (beta dependent)

The standard described "Gilbert cell", illustrated by the above schematic notated as "Howard Jones", consists of two differential amplifier stages formed by emitter-coupled transistor pairs (Q1/Q4, Q3/Q5) whose outputs are connected (currents summed) with opposite phases. The emitter junctions of these amplifier stages are fed by the collectors of a third differential pair (Q2/Q6). The output currents of Q2/Q6 become emitter currents for the differential amplifiers. Simplified, the output current of an individual transistor is given by $i_c = g_m v_{be}$. Its transconductance g_m is (at $T=300$ k) about $g_m = 40 I_C$. Combining these equations gives $i_c = 40 I_C v_{be,lo}$. However, I_C here is given by $v_{be,rf} g_{m,rf}$. Hence $i_c = 40 v_{be,lo} v_{be,rf} g_{m,rf}$. Which is a multiplication of $v_{be,lo}$ and $v_{be,rf}$. Combining the two difference stages output currents yields four-quadrant operation.

The cells invented by Barrie Gilbert, as described by the schematics noted as "Gilbert", have two additional diodes. These diodes log the input current in such a way that the exponential characteristics of the following transistors result in an, ideally, perfect multiplication of the input currents. This additional diode cell topology is typically used when a low distortion VCA (Voltage Controlled Amplifier) is required. This topology is almost never used in general RF mixer/modulator applications, with one reason being that the linearity required of the top cascode devices is minimal due to their typical square wave drive signals.

A functionally equivalent circuit may be constructed using field-effect transistors (JFET, MOSFET) or vacuum tubes.

Applications

A Gilbert cell can be used as:

- A small signal precise four-quadrant multiplier (with condition that both inputs are small compared with V_T (thermal voltage = 0.025 V)
- A large-signal phase detector (with condition that both inputs are great compared with V_T)
- A modulator in a communications application (with condition that only one input is small compared with V_T while the other input is greater)
- A pre-processing circuit in a flash ADC to reduce the number of comparators in this architecture. This is called a folding ADC.
- An exclusive-or (XOR) gate for emitter-coupled logic.

References

1. ARRL - Wes Heyward (W7ZOI), Rick Campbell (KK7B), Bob Larkin (W7PUA) - Experimental Methods in RF Design, 2003, ISBN 978-0-87259-879-9

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