A 150/400/800/1900 MHz Low Noise Cartesian Feedback IC with Programmable Loop Bandwidth

Paul Gailus

Joseph Charaska

Motorola, Inc.

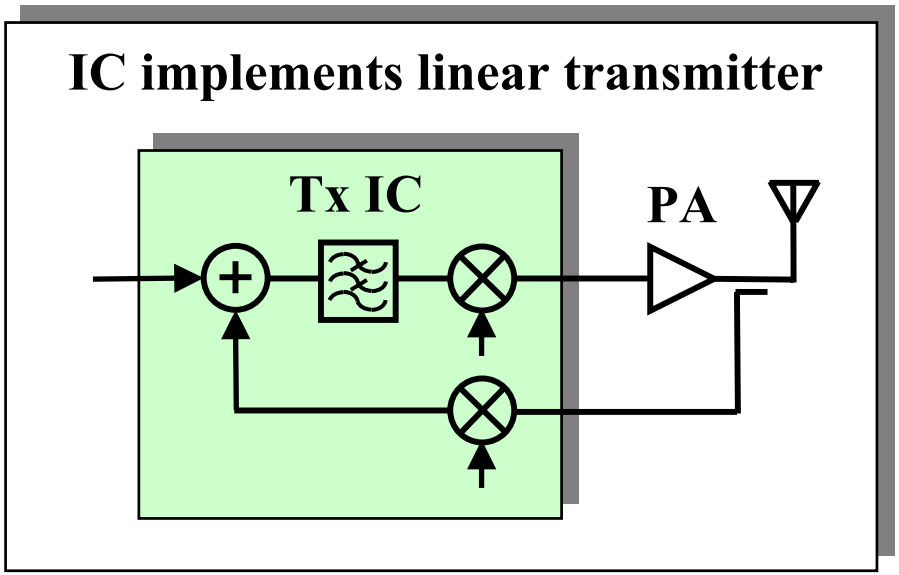
Schaumburg, Illinois USA

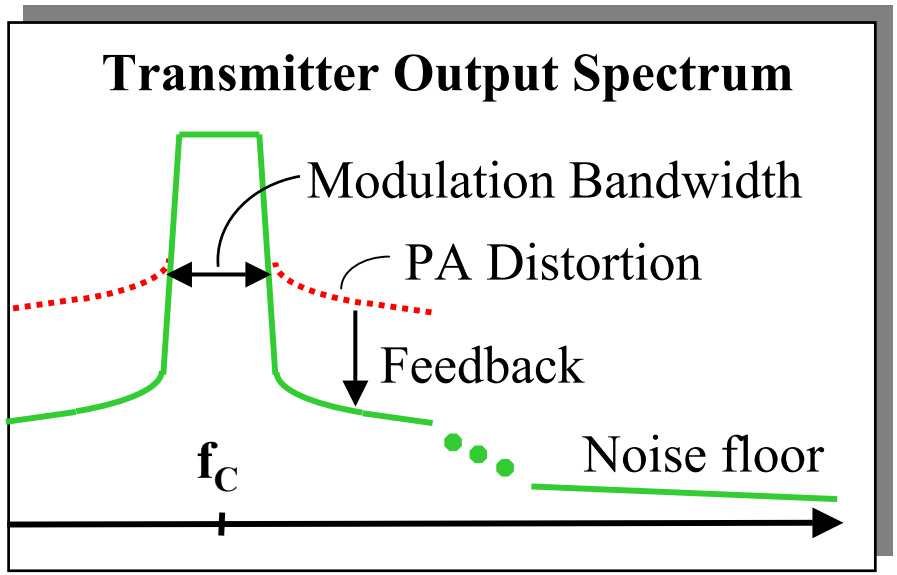
Outline

- Introduction: Cartesian Feedback Transmitter IC
  - Goals and key features
  - Issues and solutions
- Tx IC Architecture
- Loop Filter
- Modulator and Demodulator
- Local Oscillator chain
- Spectral Performance
- General Characteristics
- Conclusion

Introduction

Goal: High flexibility low noise Cartesian Feedback Tx IC

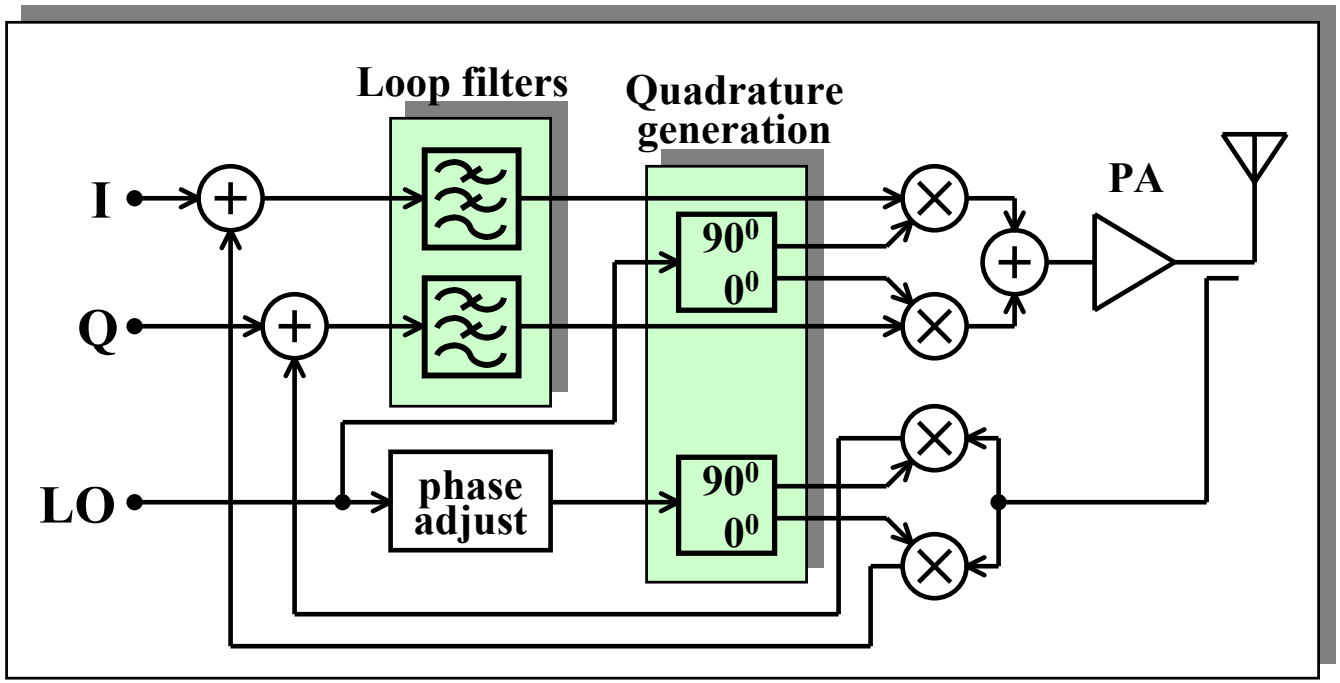




Key features:

- Supports 10:1 range of modulation bandwidths
- 150MHz, 400MHz, 800MHz, 1.9GHz operation
- Lower noise - reduces / eliminates external RF filtering

Cartesian Feedback Issues and Solutions



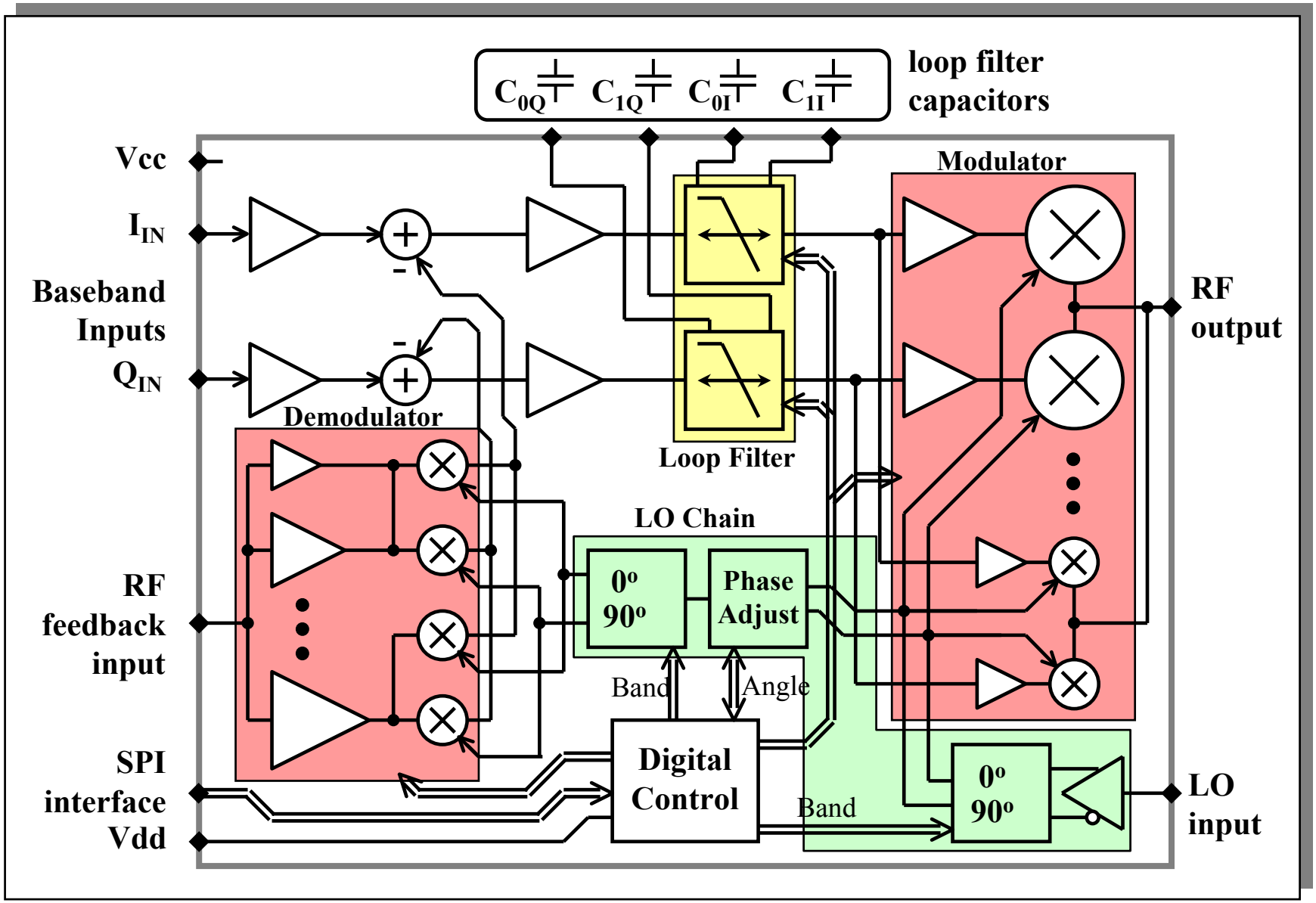
Direct Conversion:

- Eliminates image filters ☺
- 90^0 LO needed at each Tx frequency ☹
  Solution: Multiband quadrature generation

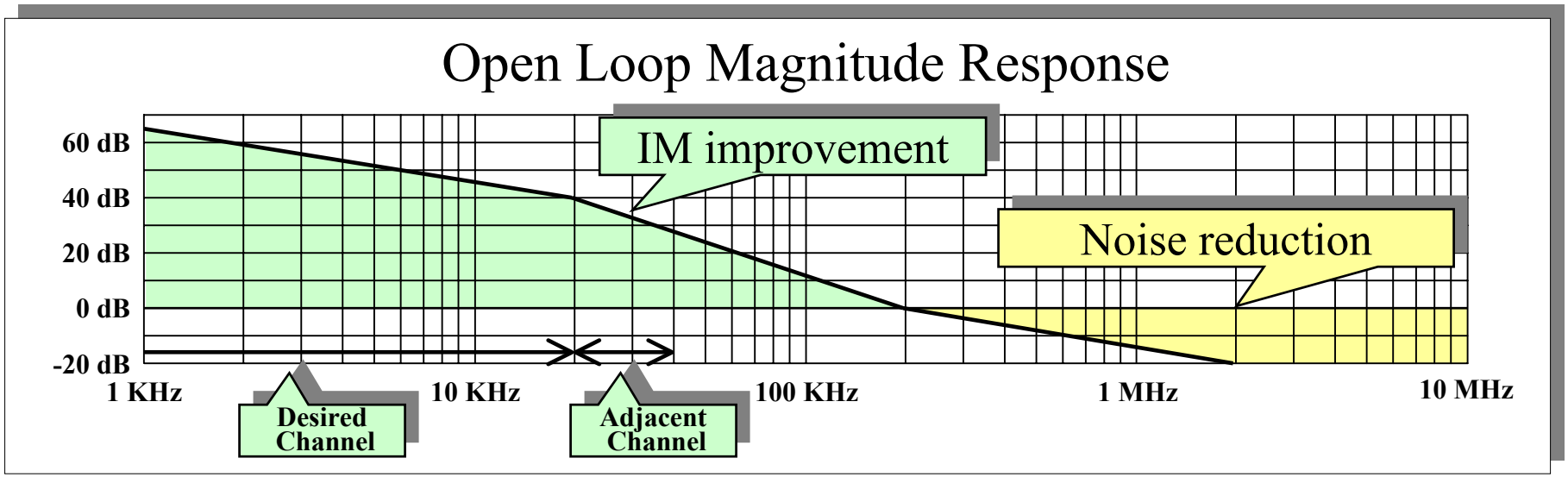
Loop Filters:

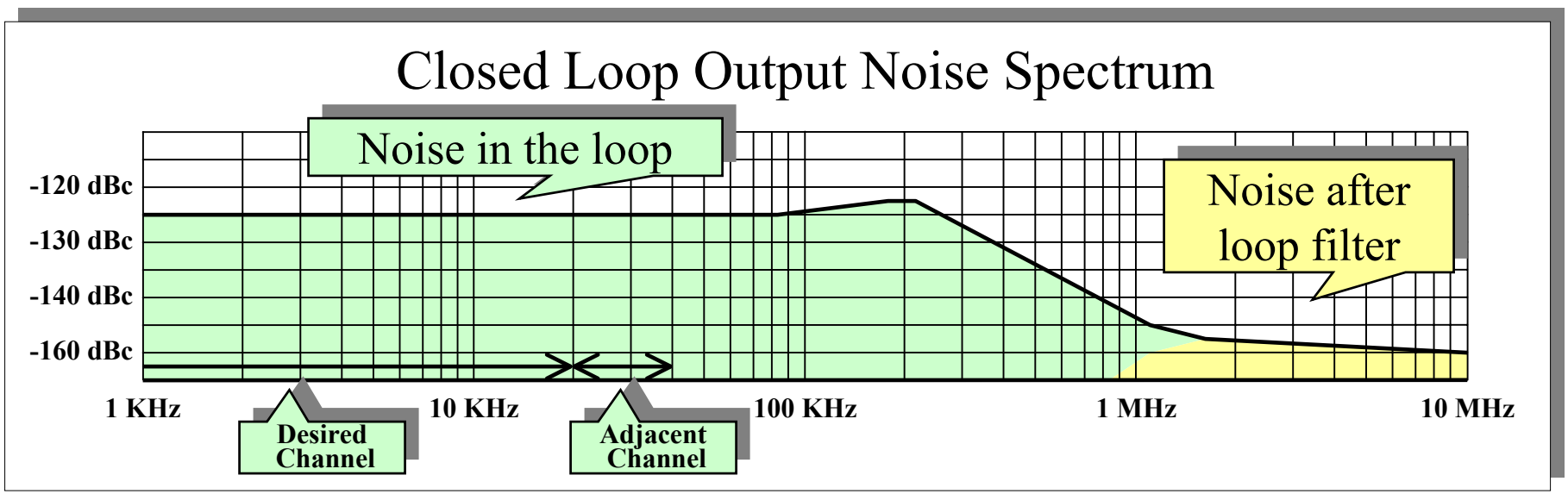
- Limit modulation bandwidths supported
  Solution: Programmable loop filters

Tx IC Architecture

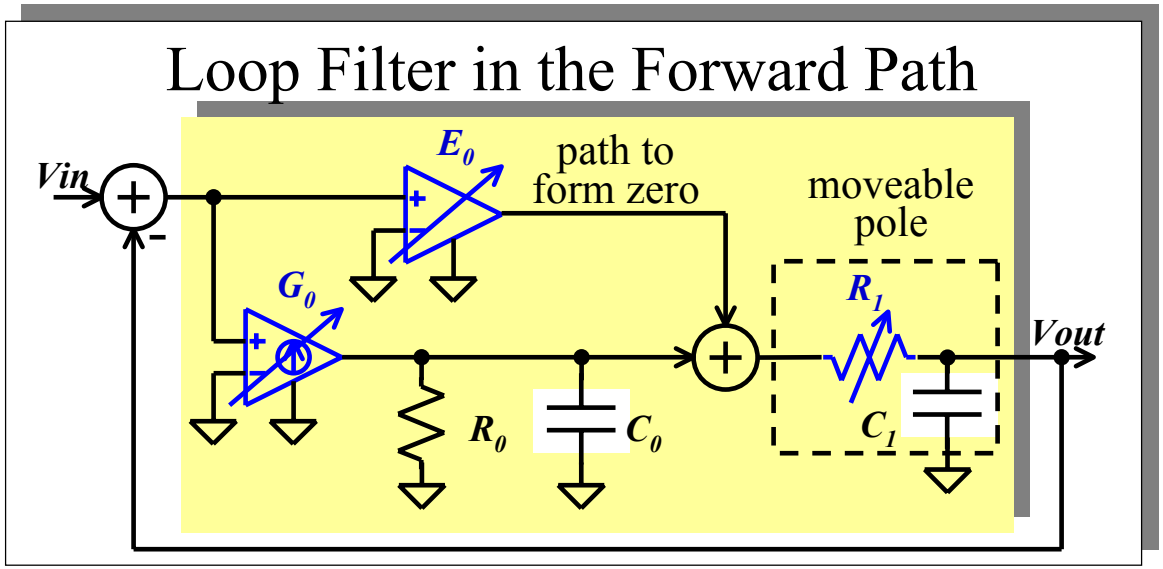


Loop Filter Design Tradeoffs



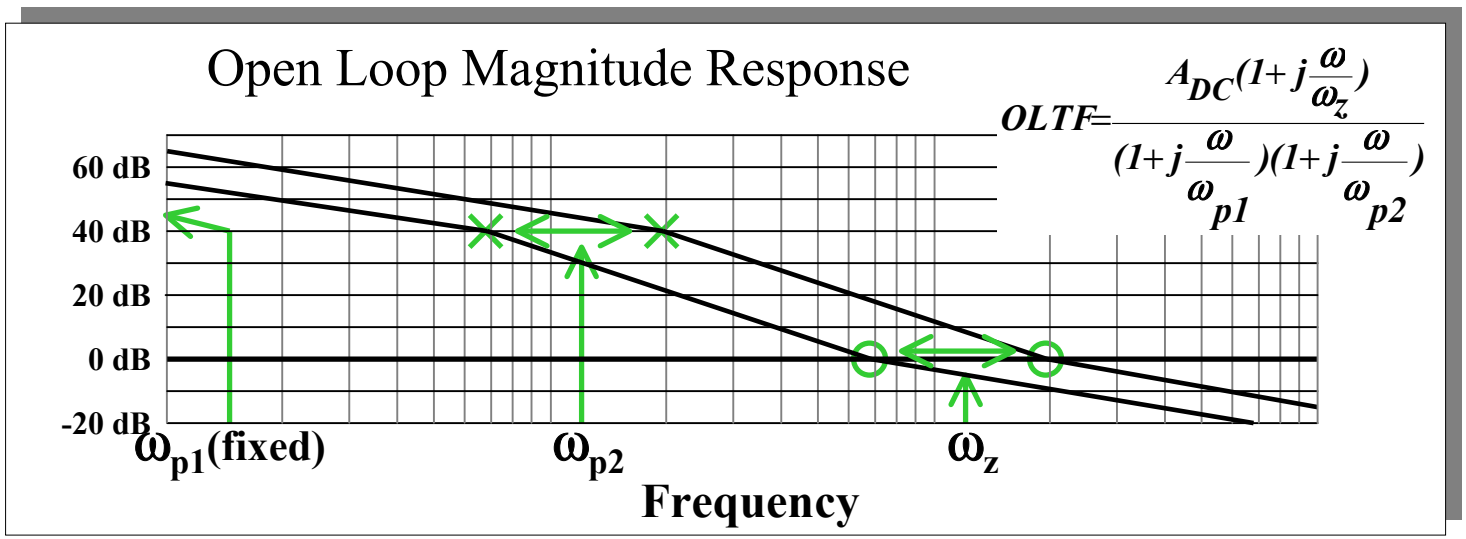


Programmable Loop Filter Topology



For lower noise:

- ✓ Large filter capacitors
- ✓ Gain placed before passive filters
- ✓ Moveable pole continues to roll-off high frequency noise



for $G_0 R_0 >> E_0$

$$A_{DC} = G_0 R_0$$

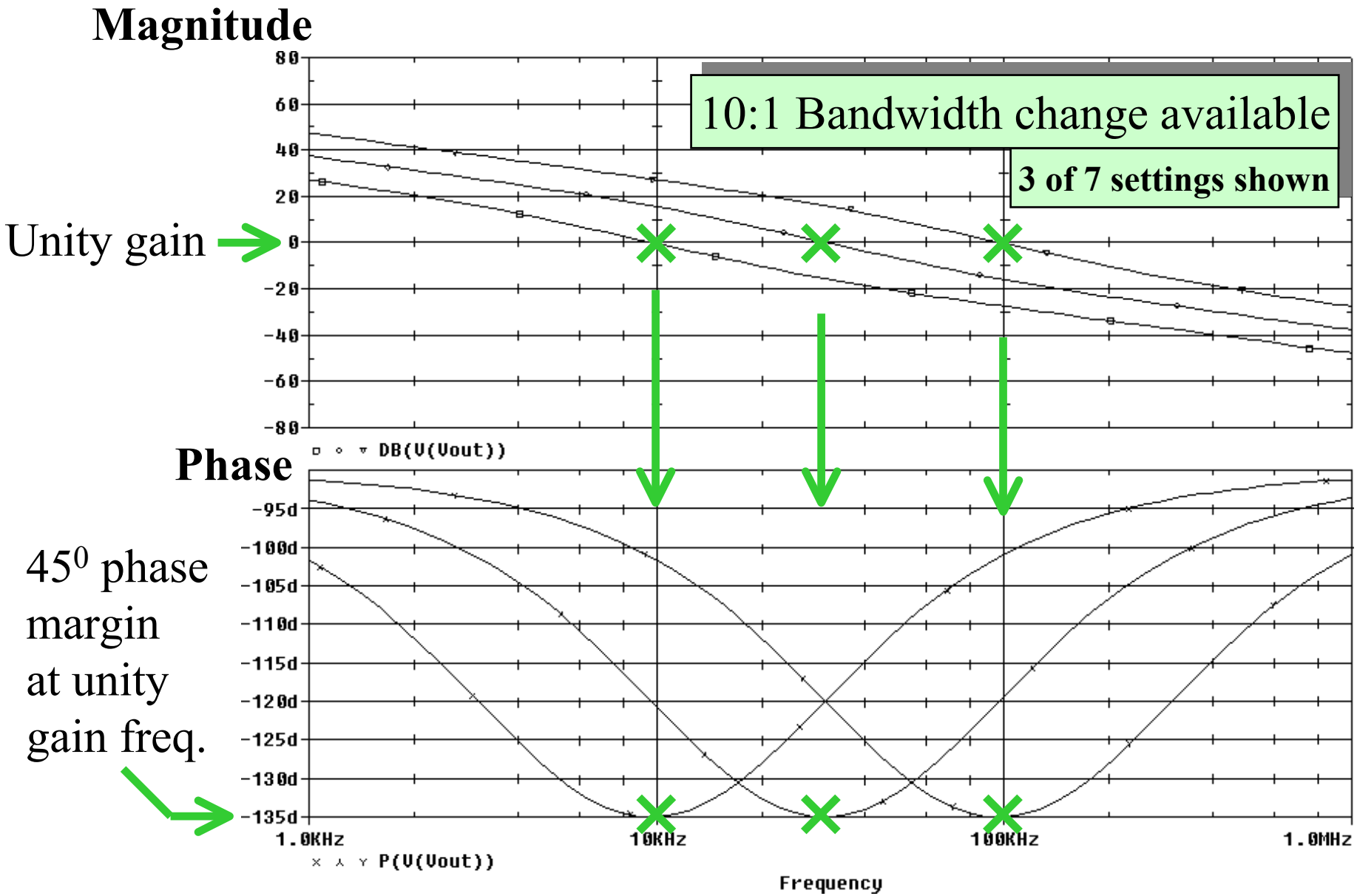
$$\omega_{p1} = \frac{1}{R_0 C_0}$$

$$\omega_{p2} = \frac{1}{R_1 C_1}$$

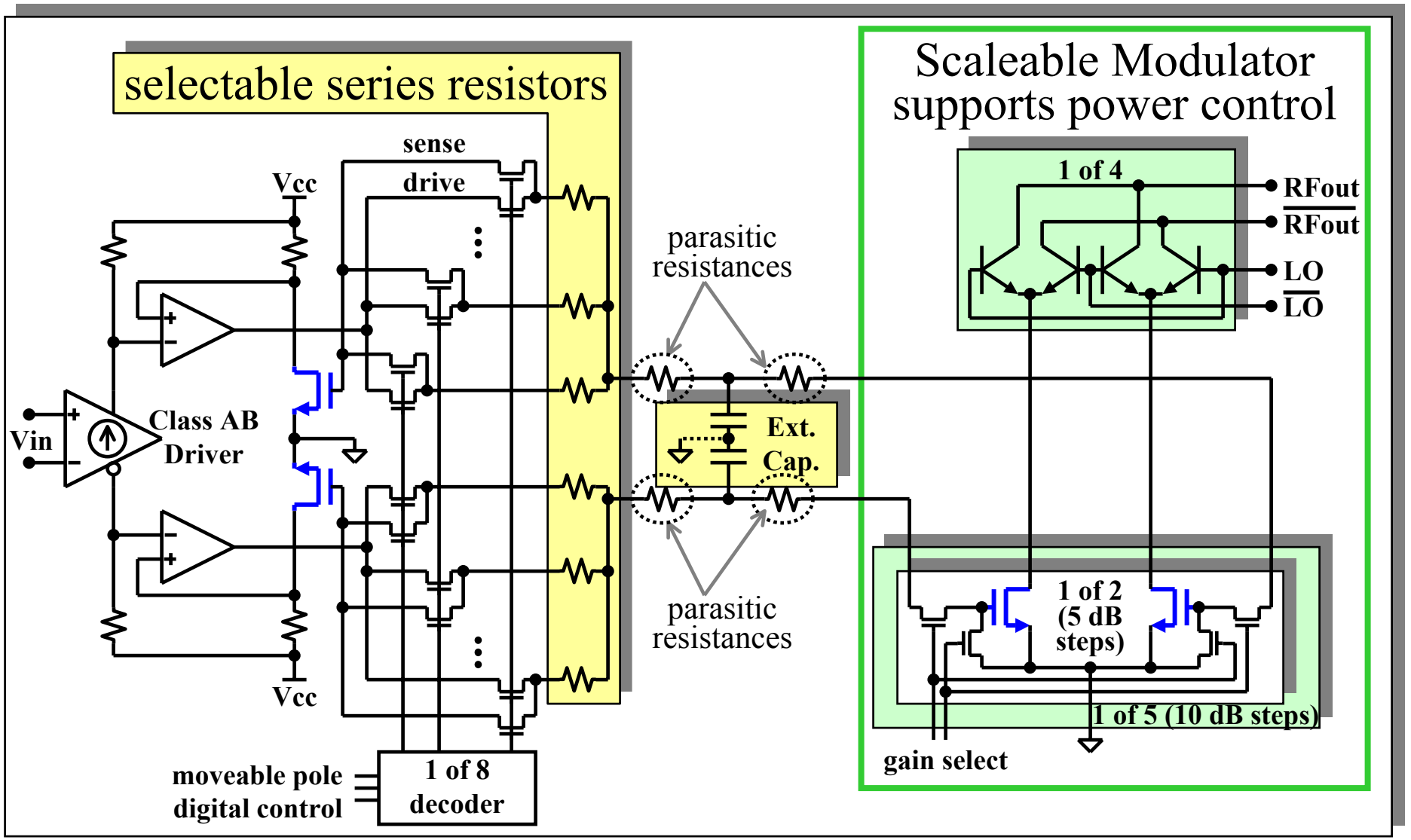
$$\omega_z = \frac{G_0}{E_0 C_0}$$

Programmable Loop Filter Response

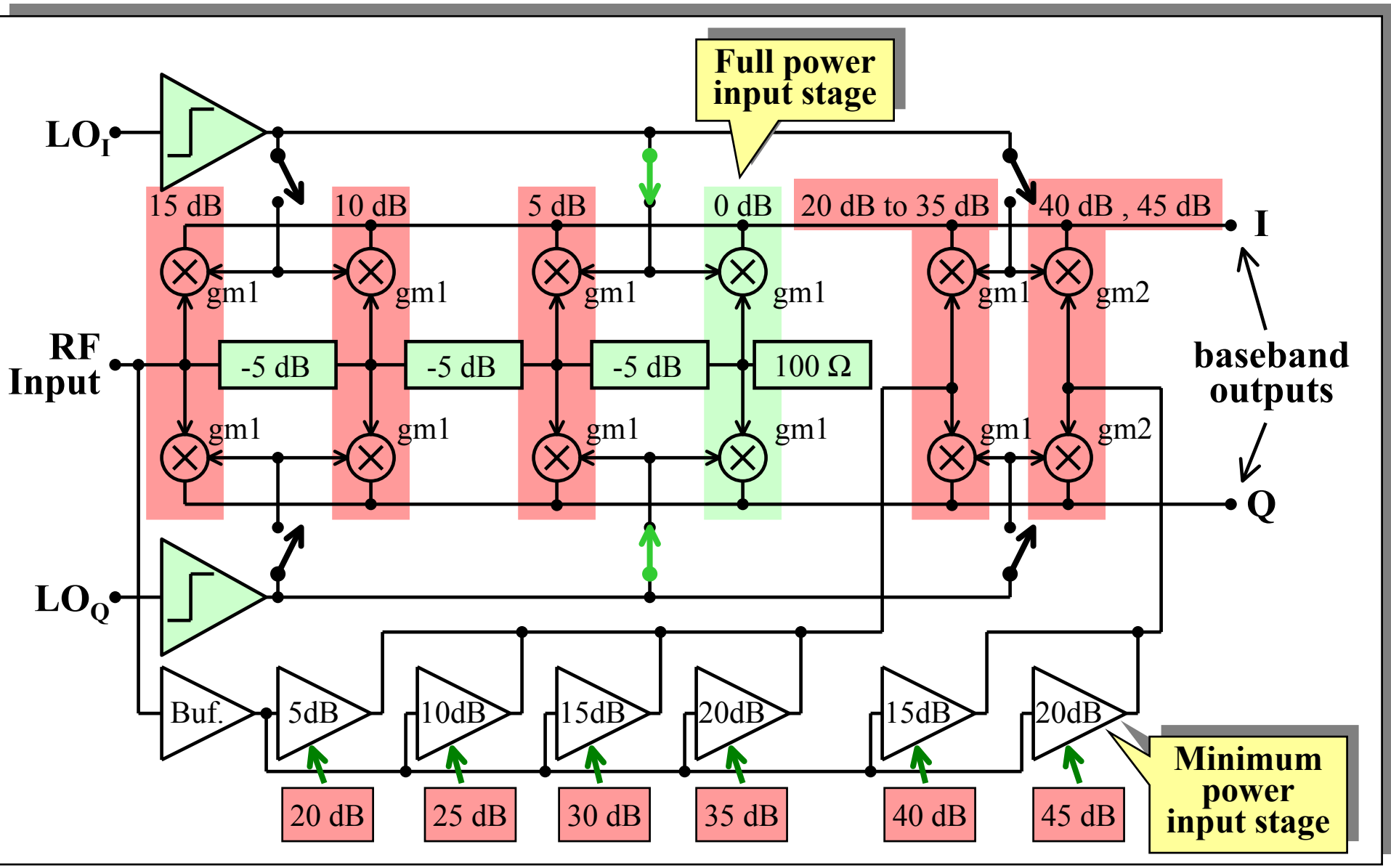
(open loop transfer function)



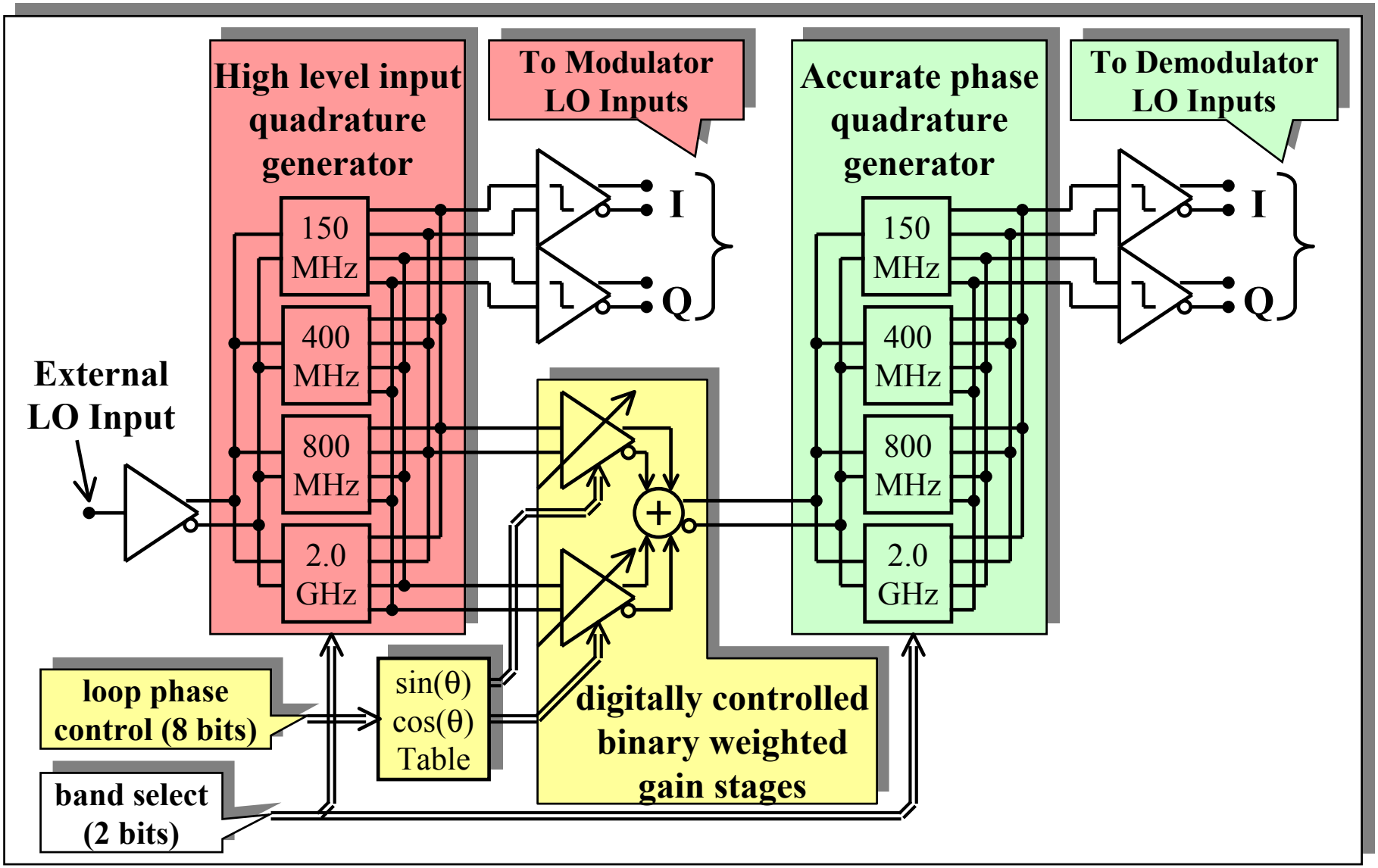
Moveable Pole and Modulator Implementation



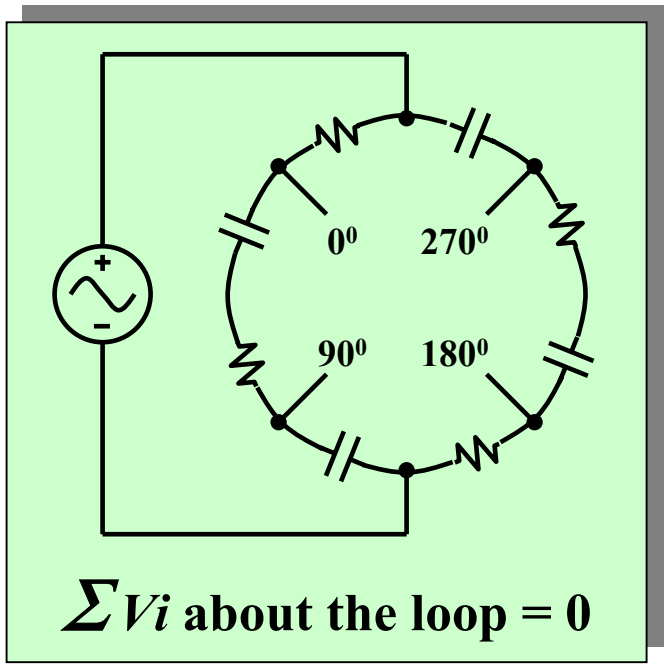
Demodulator with Power Control



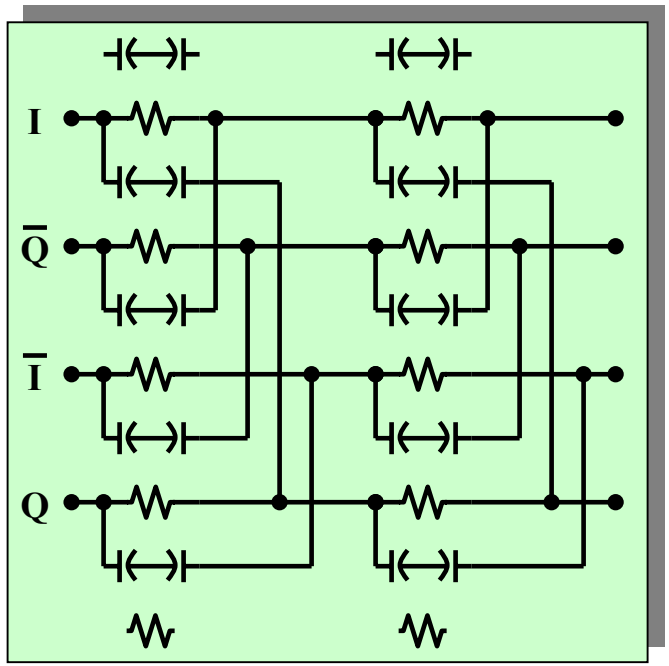
Local Oscillator Chain



Polyphase Quadrature Generator



1-stage quadrature generator



2-stages in a layout configuration

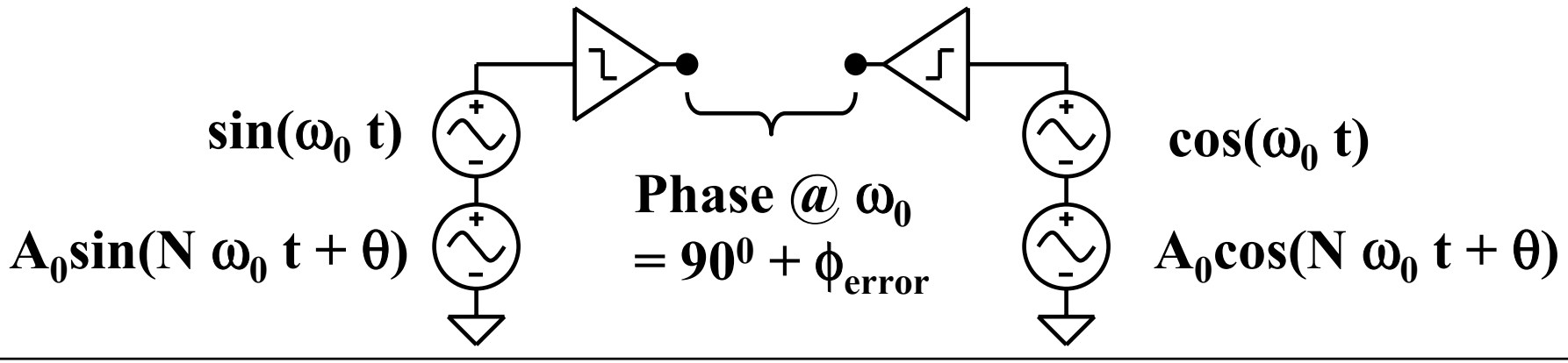
For best LO phase accuracy:

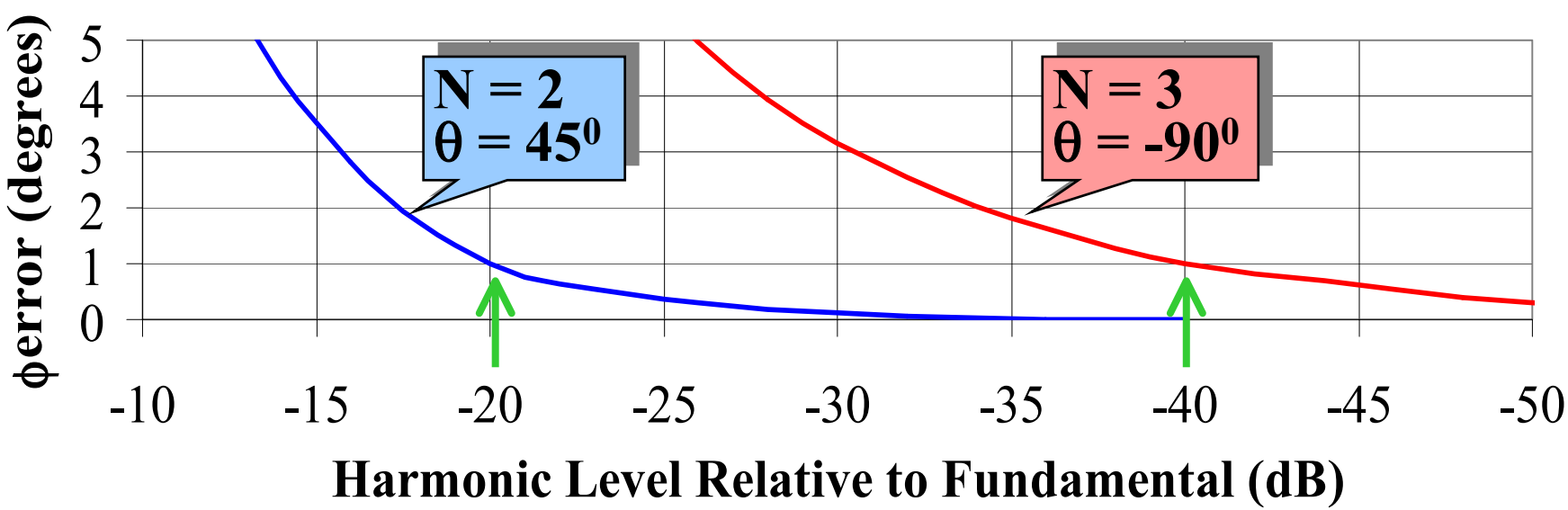
- ✓ Optimize matching
- ✓ Minimize harmonic content

For best layout:

- ✓ Use large devices
- ✓ Balance line lengths
- ✓ Minimize crossovers
- ✓ Use dummy devices to achieve symmetry

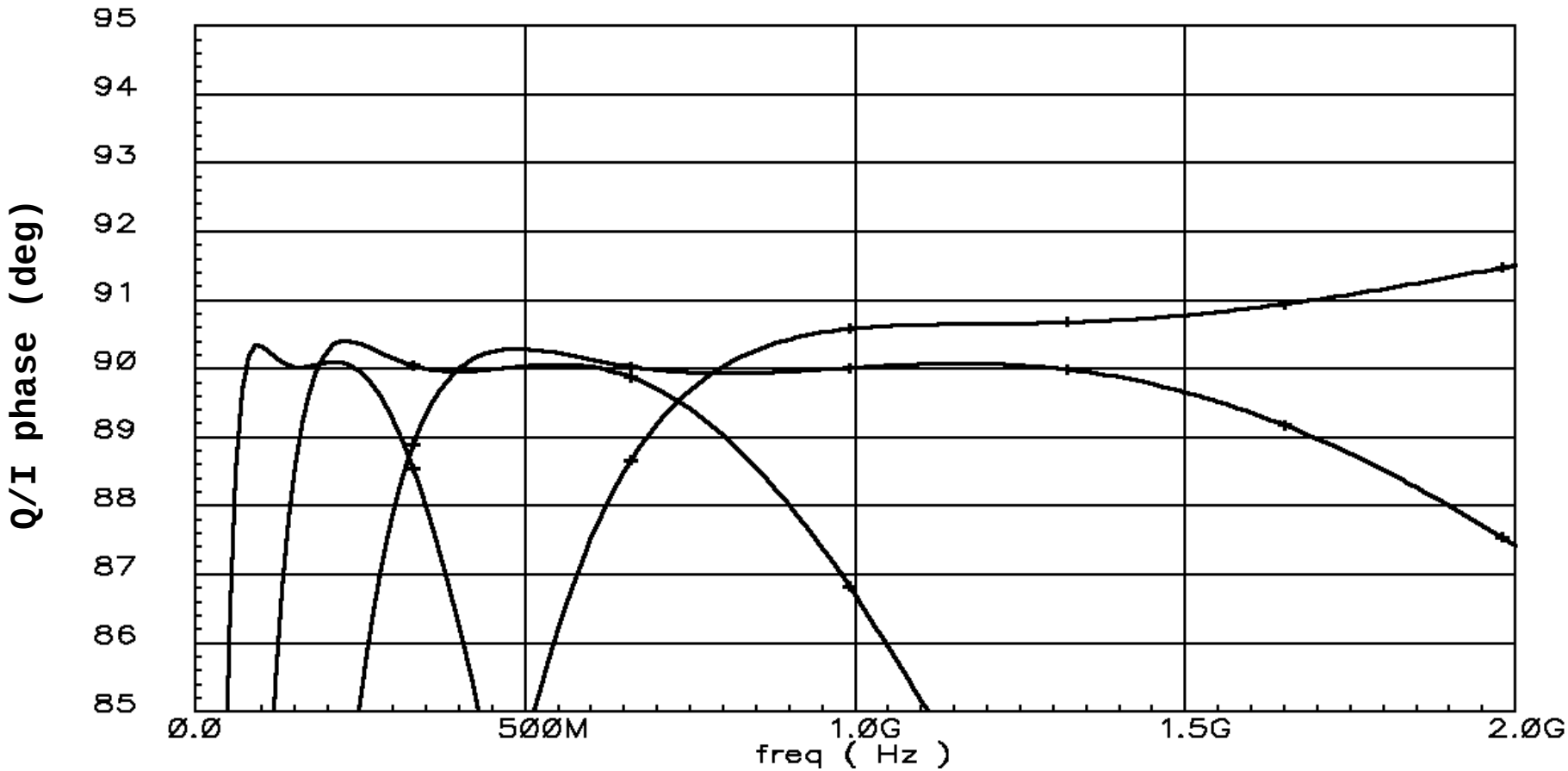
Quadrature LO Phase Error vs. Harmonic Content



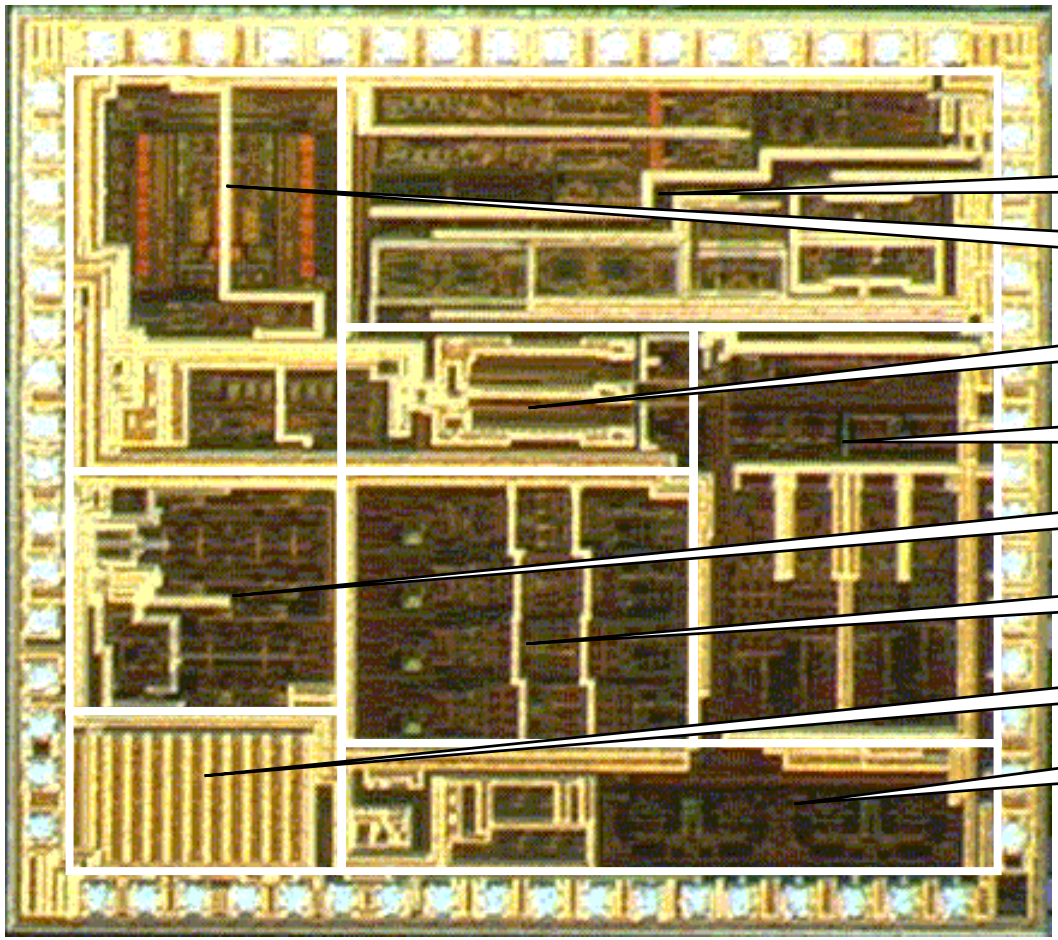


4 Band Polyphase Quadrature Generator

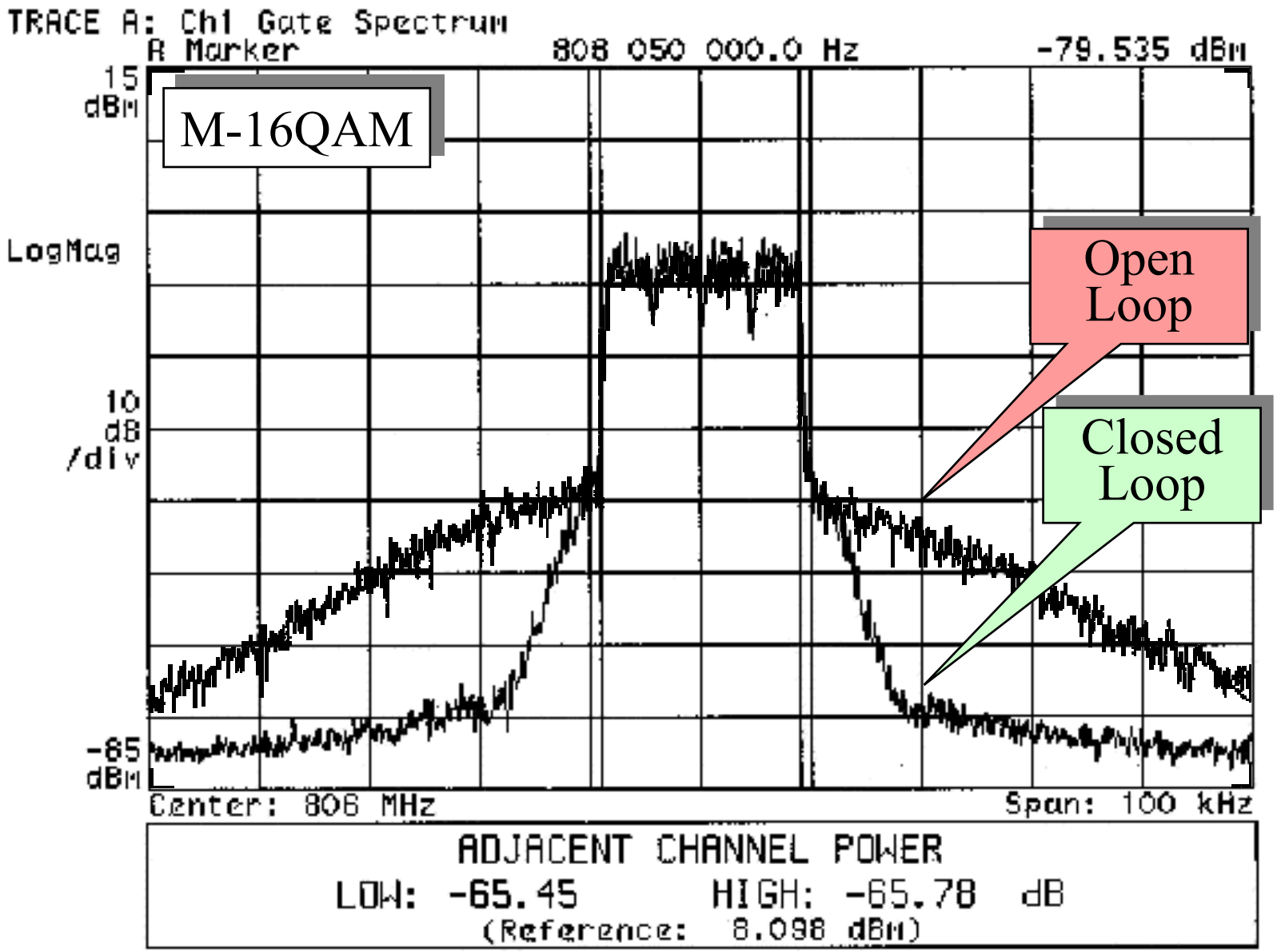
(Simulation with Layout Parasitics)



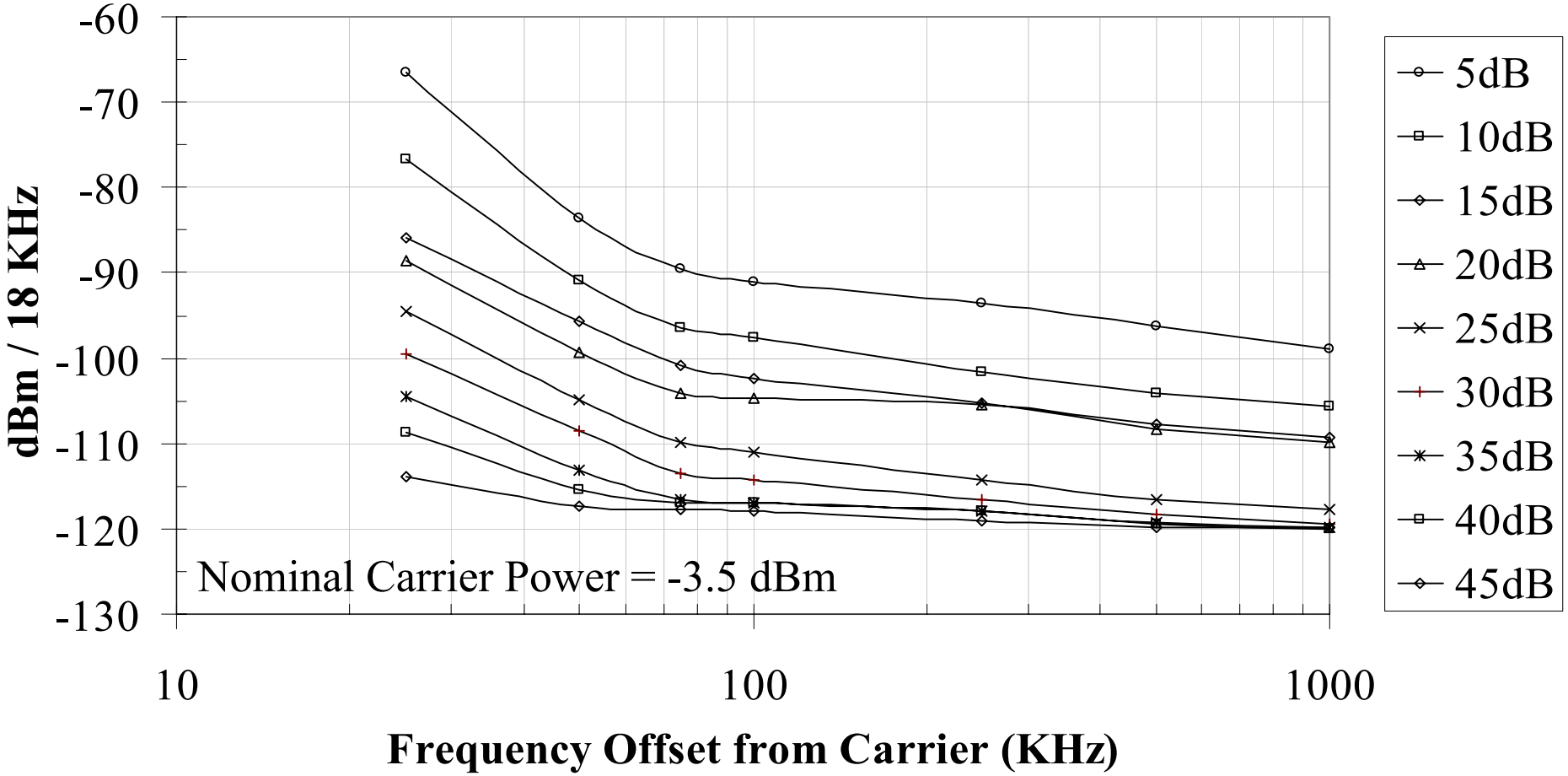
Tx IC Microphotograph



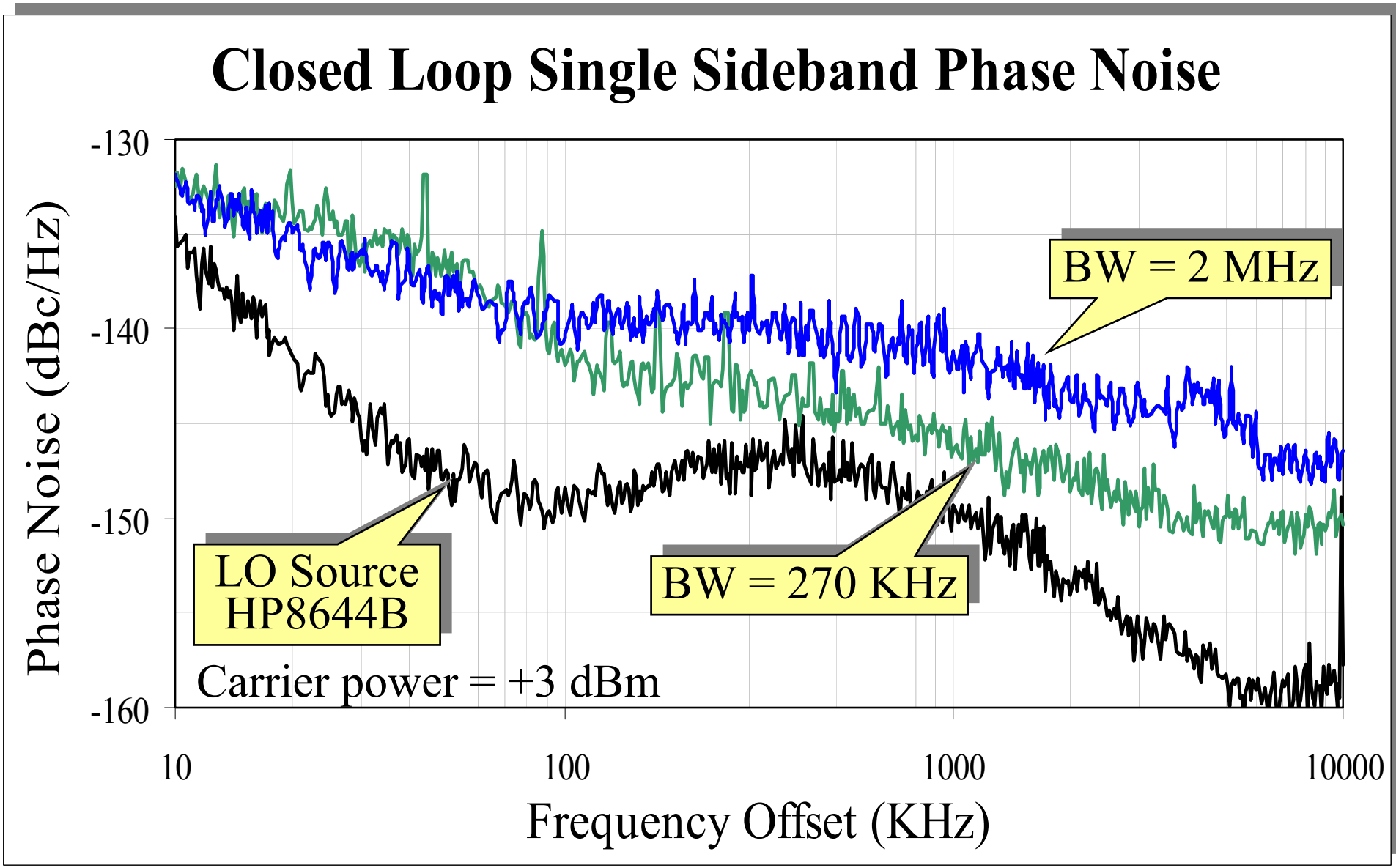
Open / Closed Loop Spectral Performance



Off Channel Noise vs. Power Control



Tx IC Noise vs. Loop Bandwidth

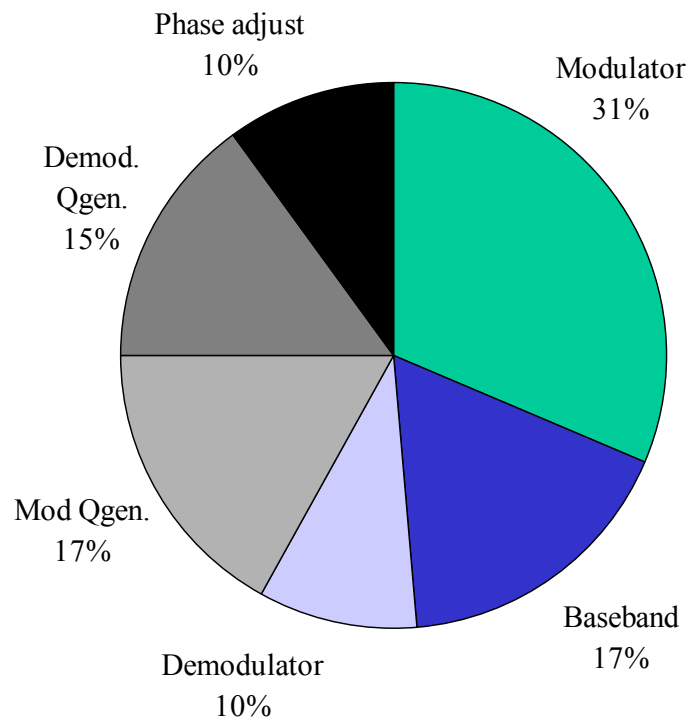


General Tx IC Characteristics

Parameter	Typical Value
Operating frequency range	100 MHz to 2 GHz (in four bands)
Baseband input level	800 mV peak differential
VCO input level	1 V peak
Peak RF feedback level	+10 dBm into 100 Ω (differential)
Peak RF output level (open collector output)	+10 dBm into 200 Ω (differential)
Output power adjustment	0 to -45 dB by 5 dB
Output noise (0 dBm average power)	-152 dBm/Hz (at a 20 MHz offset)
Output linearity (closed loop)	Better than -70 dBc 2-tone IMR
Temperature range	-40^0 C to 85^0 C
Process	IBM BiCMOS 6HP 0.25um, SiGe HBT
Die size	3.6 mm X 3.2 mm
Package	64 pin ball grid array

DC Parameter	Typical Value
Analogue supply range	2.65 VDC to 3.0 VDC
Digital supply range	1.8 VDC to 2.5 VDC
Standby Current	Less than 5µA
Operating Current vs. Power Control	200 mA (0 dB) to 162 mA (-45 dB)

Current drain apportionment



Conclusion

- **A highly flexible Cartesian Feedback TX IC has been developed and characterized**
- **Features:**
  - **Programmable loop bandwidth**
    10:1 range with same external capacitors
  - **100 MHz – 2.0 GHz operation**
    with direct conversion
  - **Low off-channel noise and high linearity**
  - **45 dB power control range (closed loop)**
- **First pass IC has met performance targets**

Acknowledgements

Development Team

•Kevin McCallum	Modulator, project leader
•Jeffery Wilhite	Quadrature generators
•John Bozeki	Digital control
•Manuel Gabato	Programmable loop filter
•Joshua Dorevitch	Baseband control
•Stephen Lai	Phase adjuster
•Rostyslav Zbotaniw	Top level layout
•Peter Bros	Interface circuitry

Evaluation Team

•Russ Melton
•Orlando Sosa
•Gus Leizerovich
•Don Dunbar
and others