IR-UWB Receiver Front-End

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ULTRA-WIDEBAND

Introduction

Introduction

- Ultra-wideband definition:

$$\frac{\boldsymbol{Bandwidth}}{\boldsymbol{Center\ Frequency}} > 0.2$$

- Impulse radio:

  Sends an impulse with large bandwidth instead of a modulated carrier

Advantages

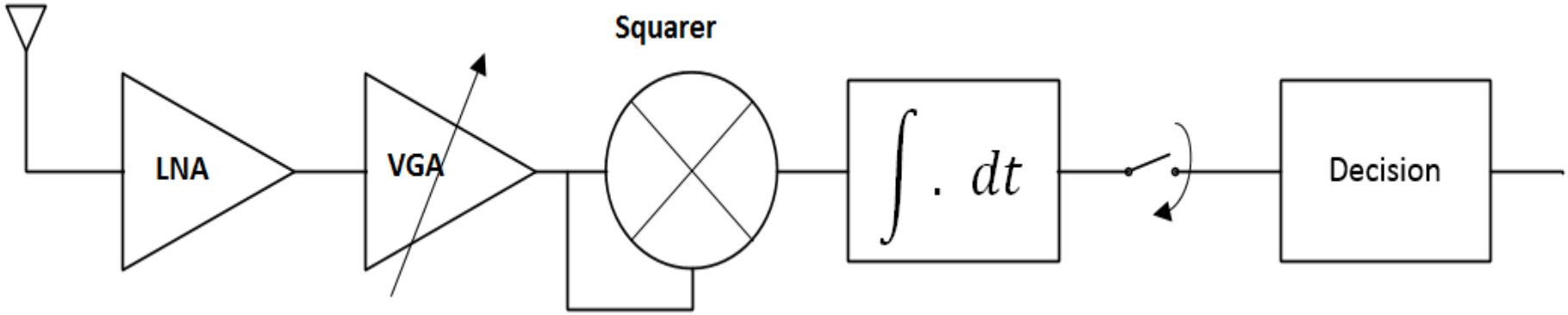
- Mainly low power consumption
- Receiver simplicity
- Sends on same band of other existing standards (no need for extra bandwidth)
- Ideal for short range low-data-rate low-power communications
- Example: Wireless sensor networks

RECEIVER SYSTEM

System Overview

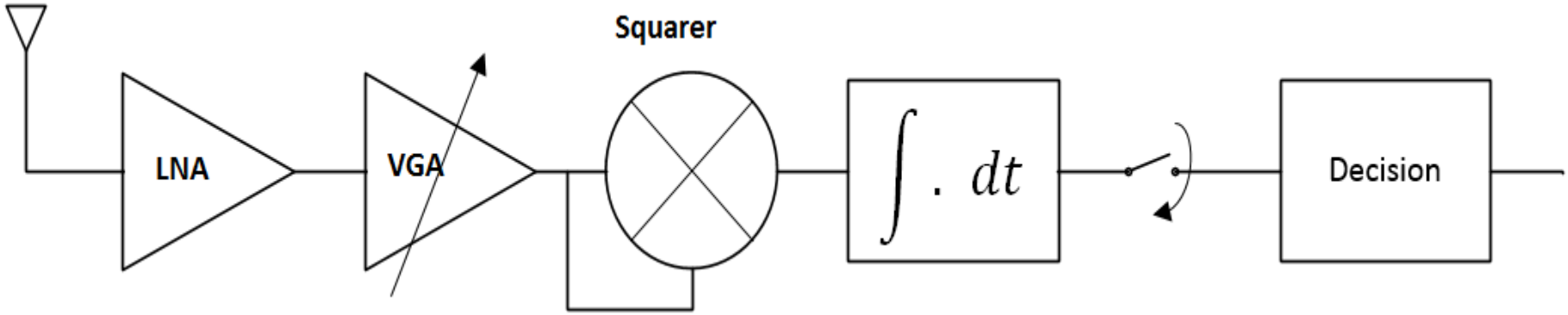
System Architecture

- Energy detection receiver
- Simple implementation
- Low power consumption



System Architecture

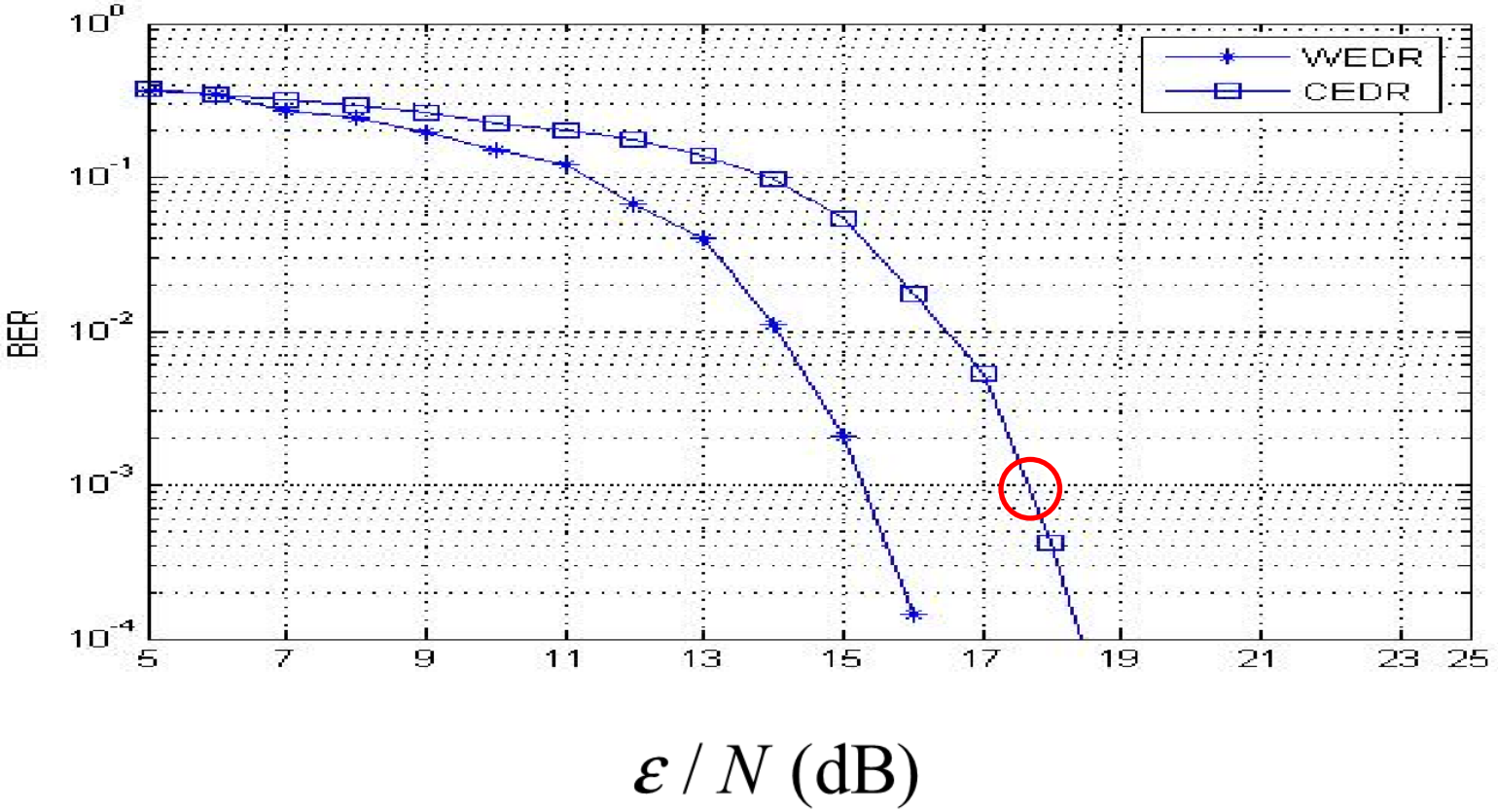
- Frequency band: 3.1-5.3 GHz
- Bandwidth 2 GHz



System Specs

- IEEE 802.15.6 standard for local and metropolitan area networks
- Sensitivity -87.2 dBm at 1 Mbps for OOK IR-UWB receivers
- $\boldsymbol{P_{sens} = -174\ dbm + 10\log(BW) + NF + SNR_{min}}$
- BW = 2 GHz

System Specs



Weighted Non-coherent Energy Detection Receiver for UWB OOK Systems. **Dazhong Mu, Zhengding Qi.** s.l. : ICSP, 2008.

System Specs

- Total noise figure < 8.8 dB

Block	Min Gain (dB)	Max NF (dB)
LNA	7	5.5
VGA	33 (max)	12
Squarer	0	30
Integrate and Dump	5	35

System Specs

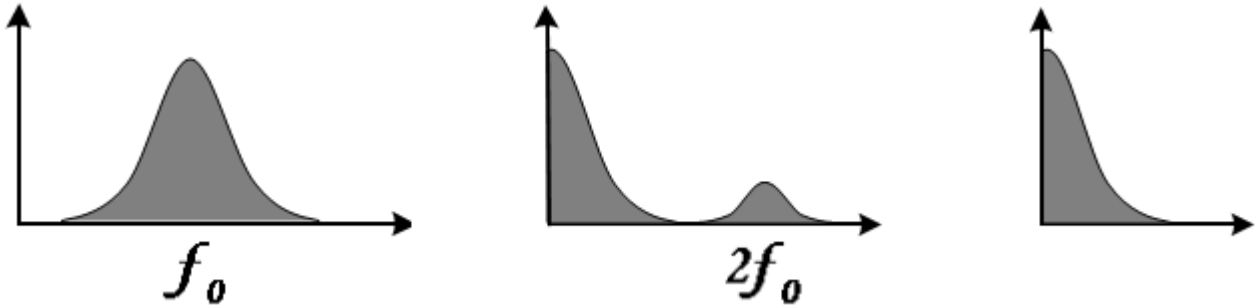
- Achieved specs for implemented blocks:

Spec	Required	Achieved at Worst Corner
LNA Gain	> 7 dB	7.6 dB
LNA NF	< 5.5 dB	5.4 dB
Squarer Gain	> 0 dB	0.9 dB
Squarer NF	< 30 dB	28.4 dB

SQUARER BLOCK

Circuit level Implementation

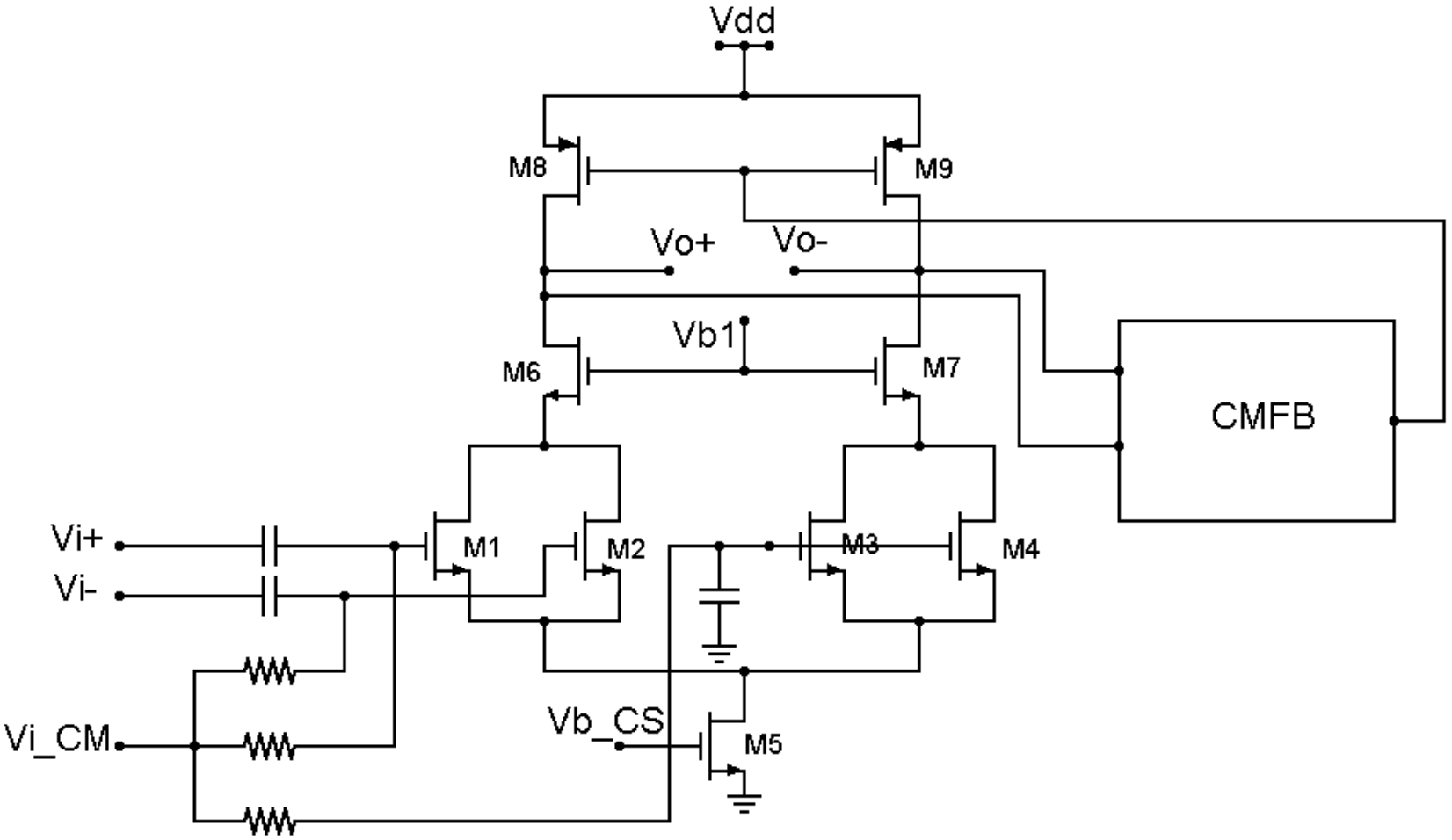
Squarer Block

- Output voltage proportional to the square of the input voltage
- 

Source: Low-Power CMOS RF Front-end for Non-Coherent IR-UWB Receiver Yuan Gao, Yuanjin Zheng Institute of Microelectronics A-STAR, Singapore

- Most mixers use Gilbert cell
- Gilbert cell requires large LO signal

Chosen Architecture

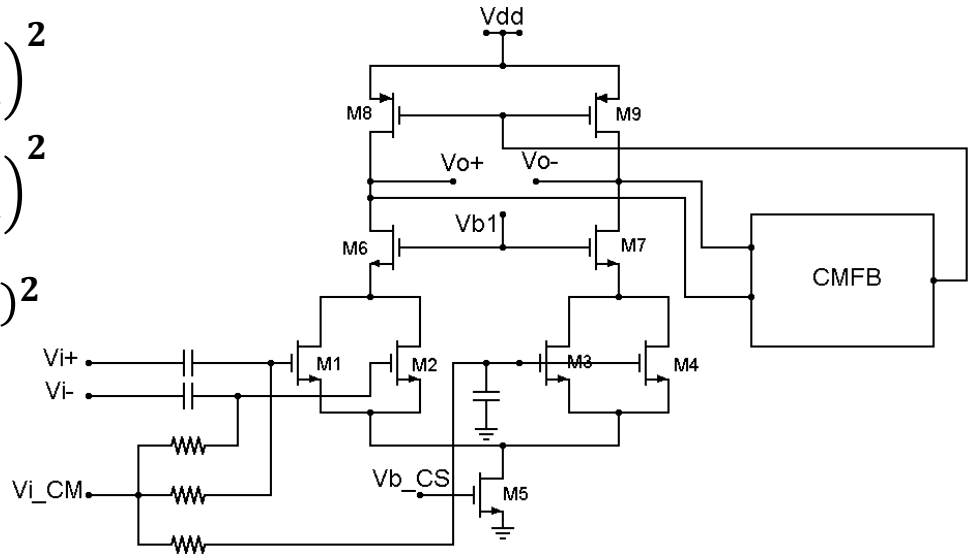


Chosen Architecture

$$I_1 = \frac{1}{2}\beta\left(\frac{W}{L}\right)\left(V_B + \frac{v_{in}}{2} - V_{th}\right)^2$$

$$I_2 = \frac{1}{2}\beta\left(\frac{W}{L}\right)\left(V_B - \frac{v_{in}}{2} - V_{th}\right)^2$$

$$I_3 = I_4 = \frac{1}{2}\beta\left(\frac{W}{L}\right)(V_B - V_{th})^2$$



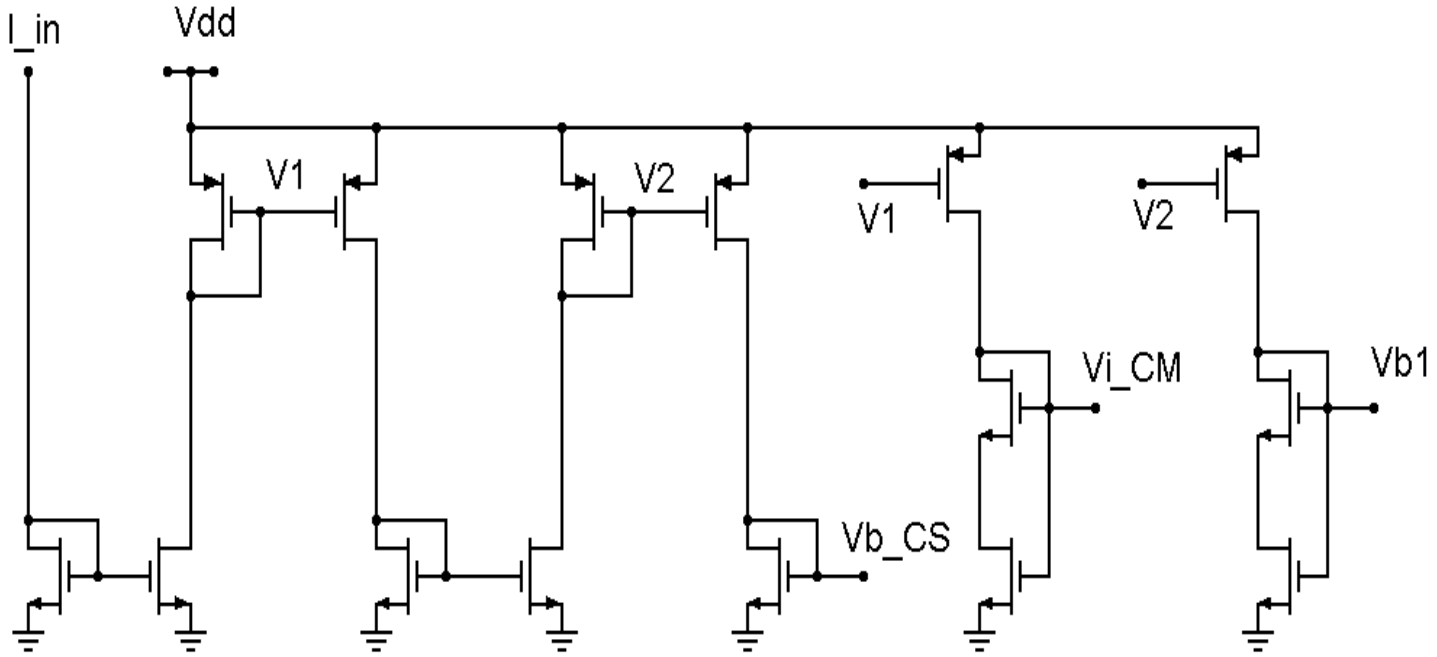
$$V_{out} = I_{out}.R_{out} = (I_1 + I_2 - I_3 - I_4).R_{out}$$

$$V_{out} = \frac{\beta}{4}\frac{W}{L}v_{in}^2 R_{out}$$

$$R_{out} \cong r_{o,M8} || \left[\left(1 + \frac{g_{m,M6}.r_{o,M1}}{2}\right) r_{o.M6}\right]$$

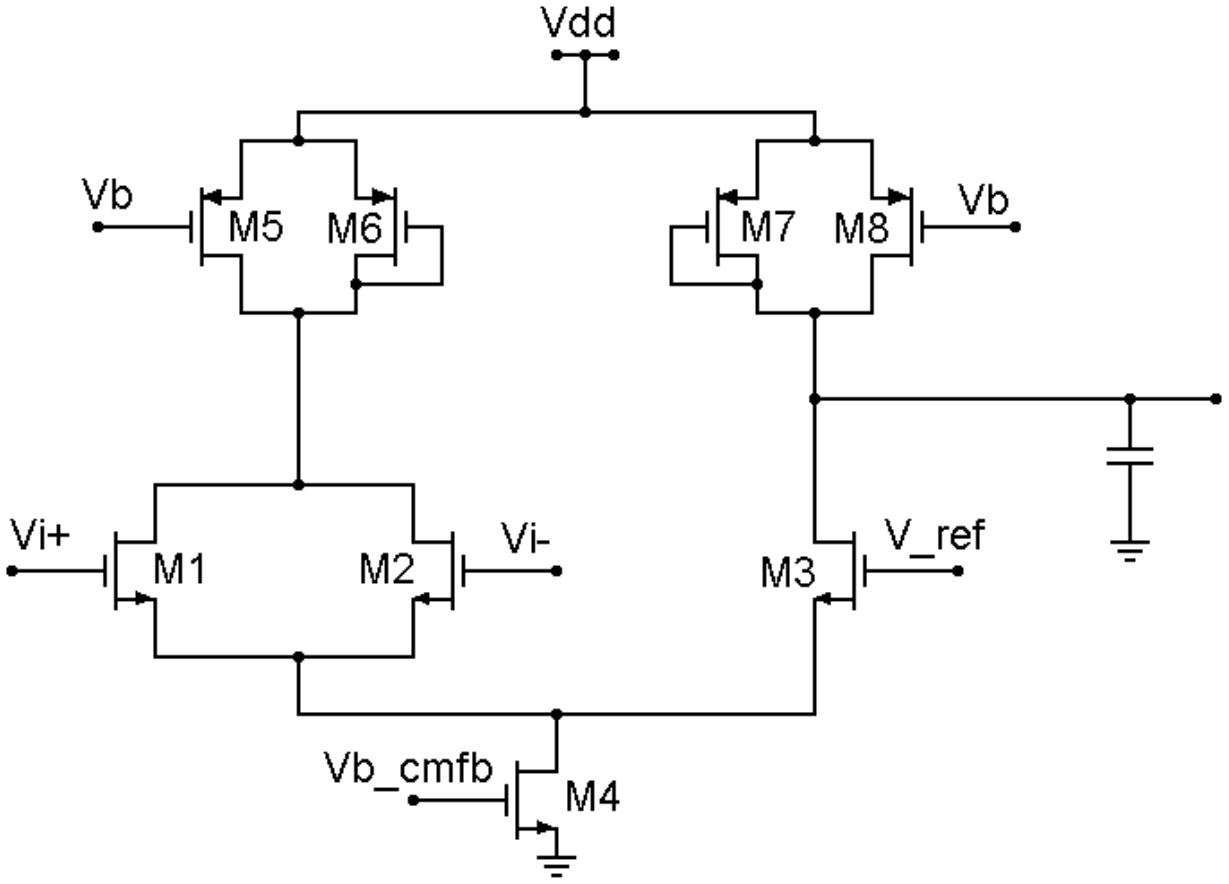
Current Mirrors

- Current mirrors to provide biasing



Common Mode Feedback

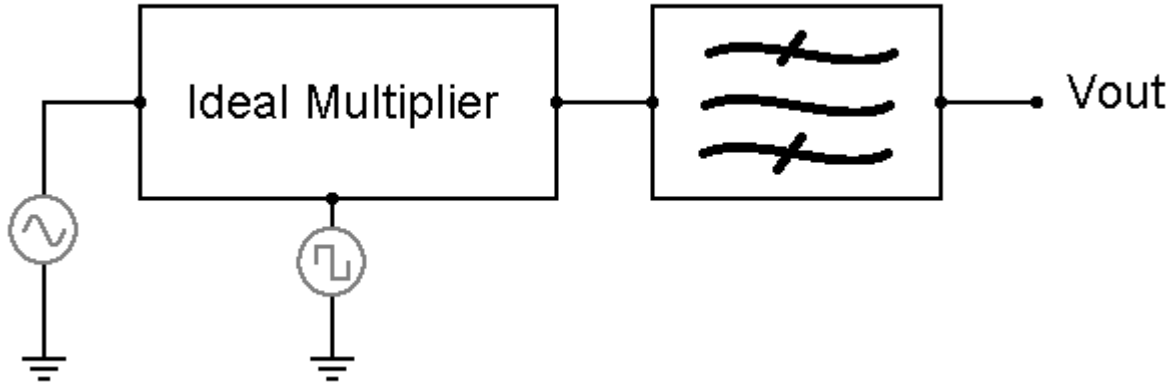
- The output node is a high impedance node

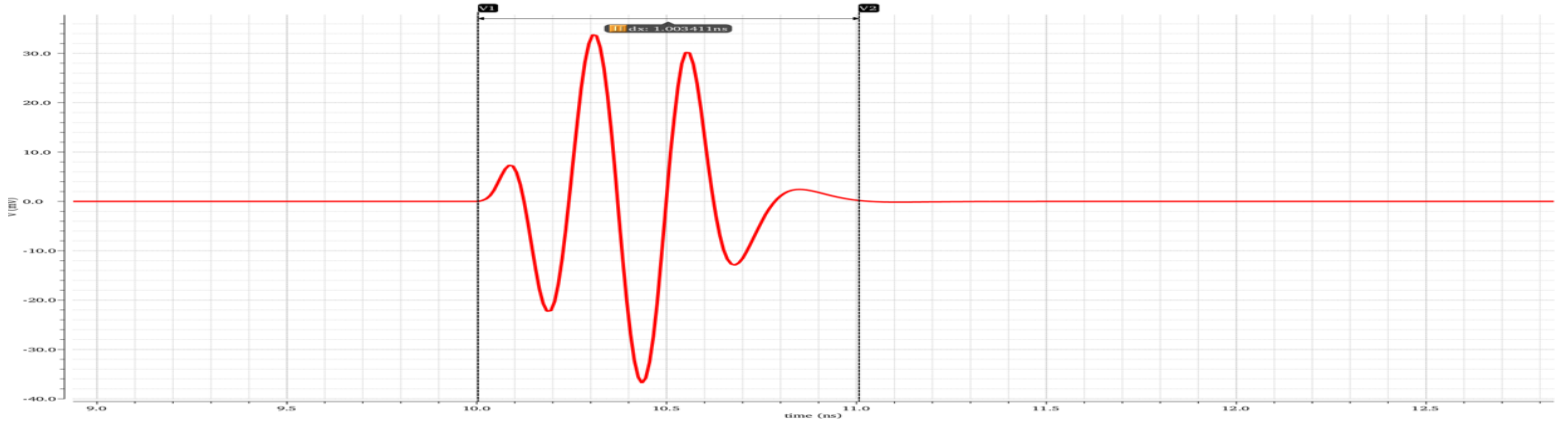


Squarer Simulation

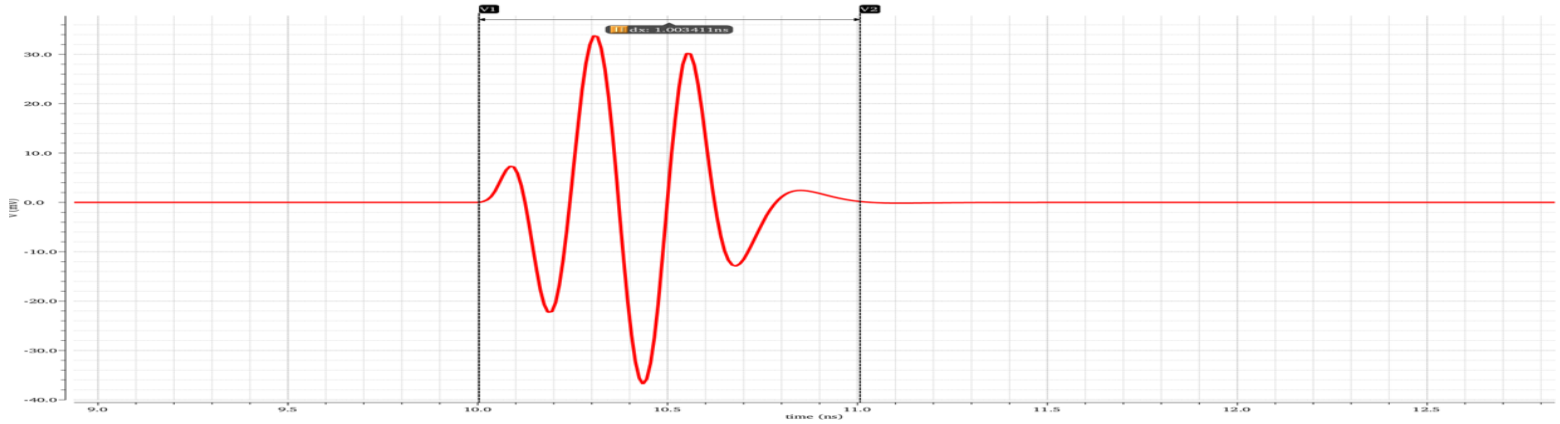
- Conventional mixer simulation is done using PSS analysis
- PSS and QPSS only work with finite number of frequencies
- Can’t be used to predict squarer behavior
- Solution : Use transient analysis

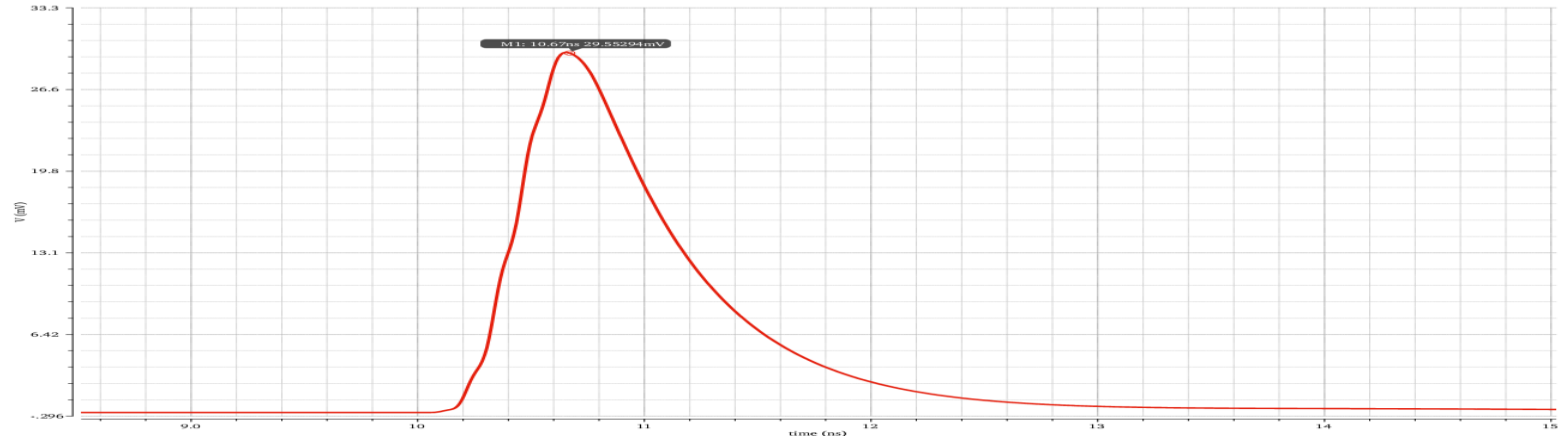
Pulse Model


Ideal Multiplier
Vout


V1
V2
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
time (ns)

Pulse Model


V1
V2
dx: 1.003411ns
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
V (dB)
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
time (ns)


M1: 10.67ns 29.55294mV
33.3
26.6
19.8
13.1
6.42
-.296
V (mV)
9.0
10
11
12
13
14
15
time (ns)

Conversion Gain

- The gain is defined using RMS values of output and input
- Results:

Parameter	Min	Typical	Max
Peak output	8.7 mV	29.6 mV	53.86 mV
RMS output	0.173 mV	0.679 mV	1.304 mV
RMS gain (ratio)	0.342	1.336	2.567
RMS gain (dB)	-9.3	2.516	8.19

Noise Simulation

- Can’t use Noise or Pnoise
- Solution : Use transient noise
- $v_{no}^2 = \frac{v_{no,RMS}^2}{F_{max}}$
- F_{max} is maximum noise frequency of simulation
- $NF = 10\log(1 + \frac{v_{no}^2}{4KTR_s*(RMS_GAIN)^2})$

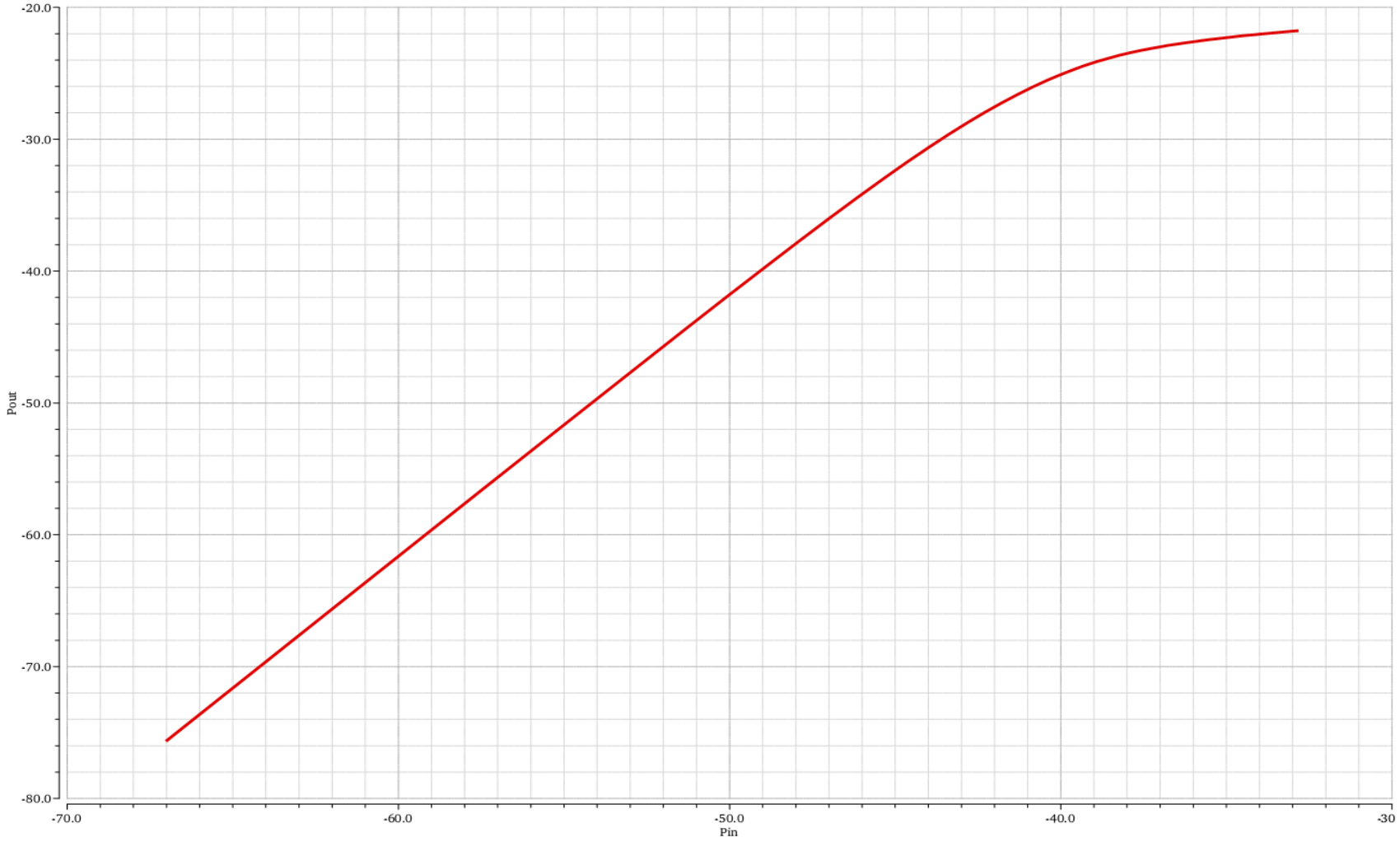
Noise Results

Parameter	Min NF	Typical	Max NF
v_{no}^2	820.4e-18 V^2	445.2e-18 V^2	66.98e-18 V^2
NF (dB)	21.798	24.8	28.405

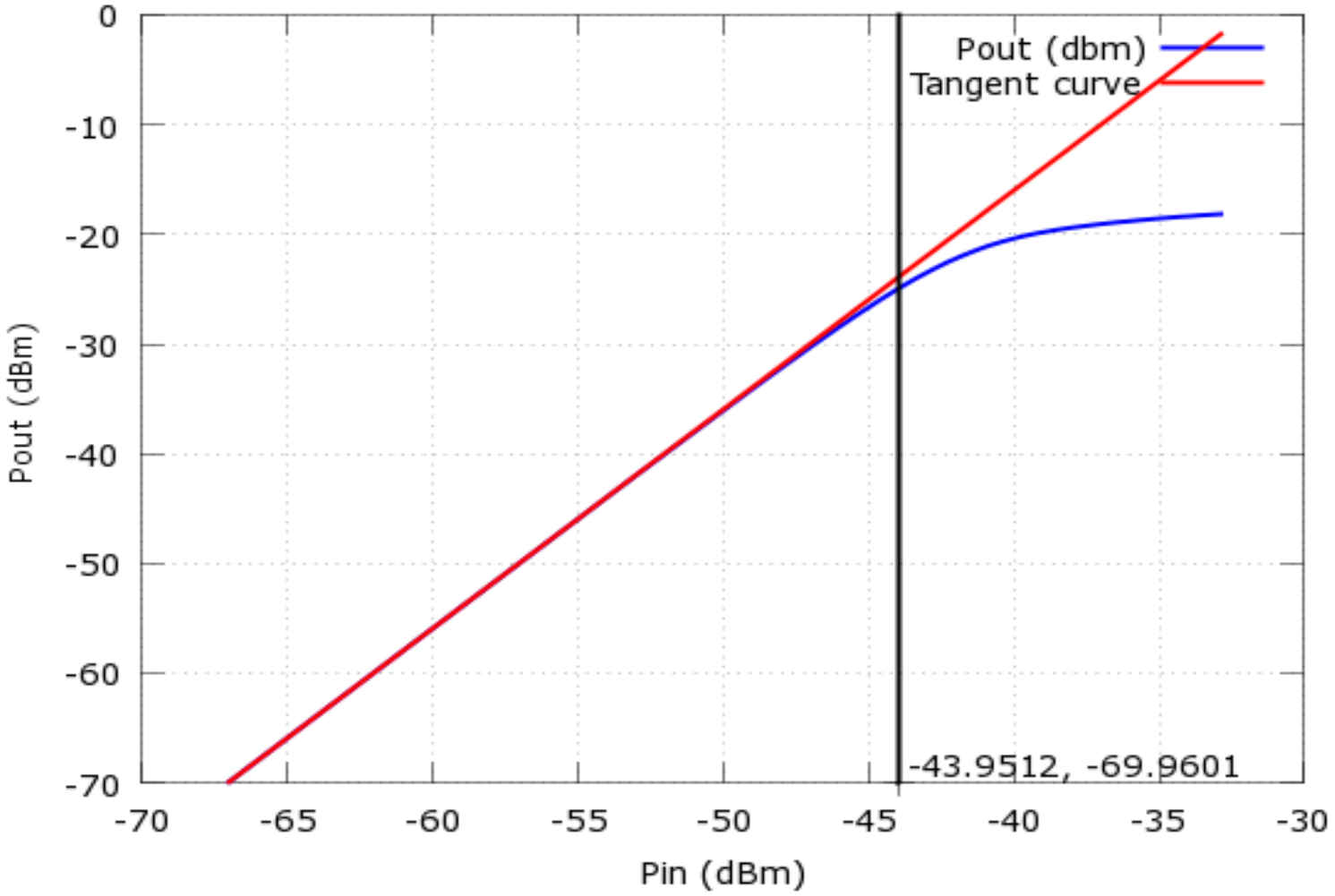
Gain Compression

- Mainly second order non-linear block
- Sweep on input amplitude of pulse
- Each time calculate RMS gain and average power

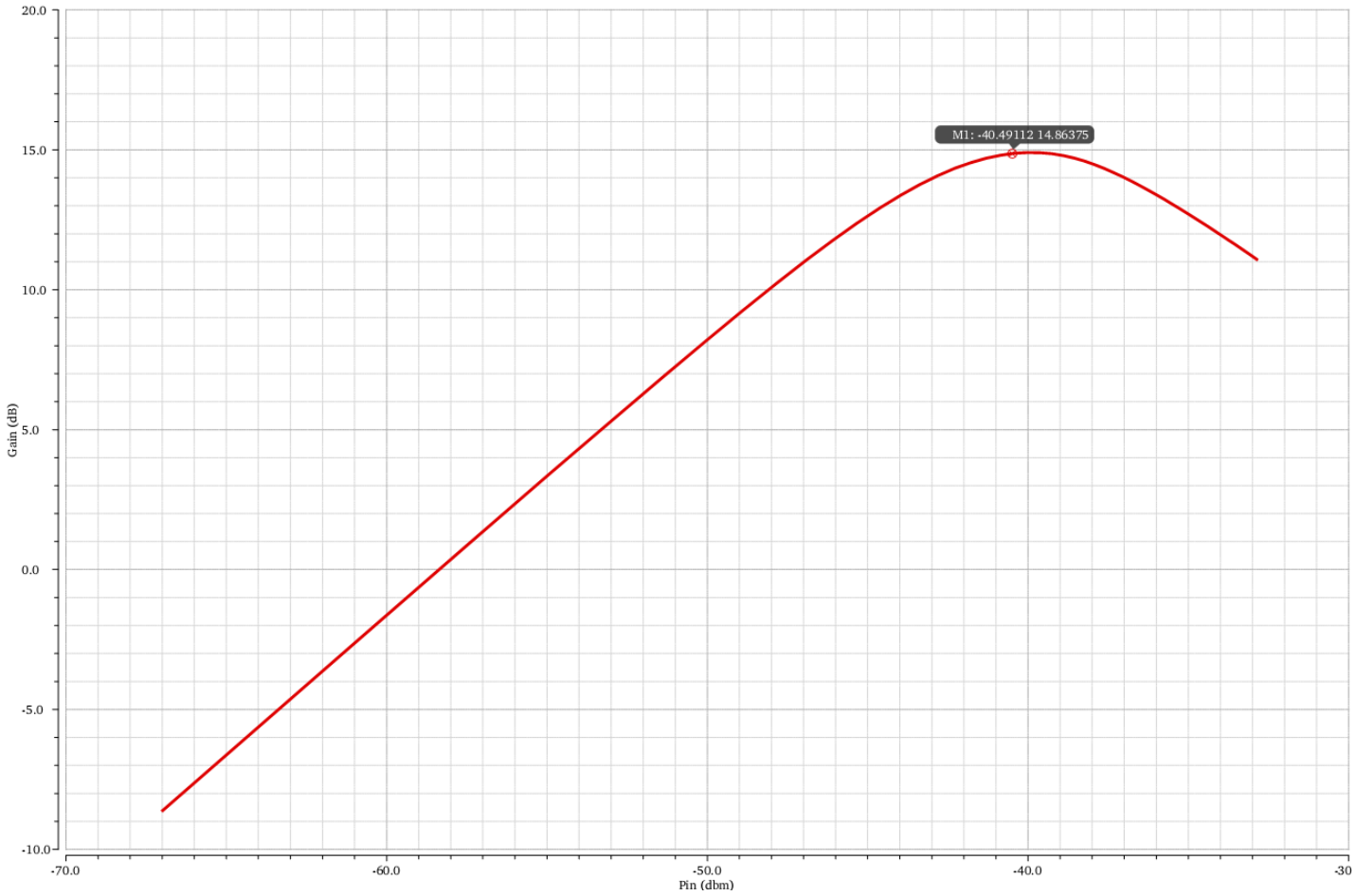
Pout - Pin



Pout - Pin


Pout (dbm)
Tangent curve
-43.9512, -69.9601
Pout (dBm)
Pin (dBm)
0
-10
-20
-30
-40
-50
-60
-70
-70
-65
-60
-55
-50
-45
-40
-35
-30

Gain - Pin


M1: -40.49112 14.86375
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
Gain (dB)
-70.0
-60.0
-50.0
-40.0
-30
Pin (dbm)

Specs Summary

Spec	Required	Achieved
Gain	> 0 dB	0.9 dB
NF	< 30 dB	28.4 dB
Power	< 10 mW	4.67 mW