5.4 AD534T Four Quadrant Analog Multiplier

5.4.1 Scope

The purpose of this analysis is to model the Analog Devices AD534T Analog Multiplier.

Analysis:	**5.4 AD534T Analog Multiplier**
Last Rev Date:	**1/18/2002**
Publication Number:	**AD534_b.pdf**
Revision:	**1999 - Rev B**
SPICE File	**AD534T.CIR**

5.4.2 Functional Description

The AD534T is a four quadrant analog multiplier with three fully differential inputs and programmable gain. The X and Y inputs are multiplier inputs. The Z input is a summing input. The output is given by Vo = A((X2-X1)(Y2-Y1)/SF – (Z1-Z2)). In the basic connection, this simplifies to Vo = (X2-X1)(Y2-Y1)/10V. The gain, A is 70dB. The scale factor, SF is 10V, but can be adjusted by adding an external resistor.

5.4.3 Assumptions and Comments

The device parameters that are modeled are listed in table 5.4.1.

1. Temperature dependence is modeled for input and output offset voltage, input Bias and Offset Current, and scale factor.
2. Input bias current vs. temperature and vs. scale factor is modeled to agree with fig. 17 of the manufacturer's data sheet. At 25C, I bias is 425nA rather than 800nA. Input offset current is scaled down by the same ratio.
3. Input offset current vs. temperature is not specified by the manufacturer, but is modeled to change in the same proportion as input bias current.
4. Output voltage swing vs. supply voltage s modeled to agree with fig. 16 of the manufacturer's data sheet.
5. Common mode rejection vs. frequency is modeled to approximately agree with fig. 18 of the manufacturer's data sheet.
6. Input voltage range (differential) is modeled to be 1.25 times the scale factor. Dependence on supply voltage is not modeled. Common mode input voltage range is not modeled.
7. Frequency response is modeled to agree with fig. 22 of the manufacturer's data sheet, which shows a small signal bandwidth of 0.87 MHz rather than 1 MHz. The change in frequency response with capacitive load is accurately modeled. Frequency response with 10X feedback attenuator, with and without capacitive load is approximately modeled as well.
8. Noise spectral density (RTO) is modeled to agree with fig. 20 of the manufacturer's data sheet.

9. The change in scale factor , SF with external resistance is modeled correctly, as well as the change in voltage at the SF pin.
10. Power dissipation is correctly modeled by the correct simulation of quiescent supply current and the correct steering of load current to either the positive or negative power supply as applicable.

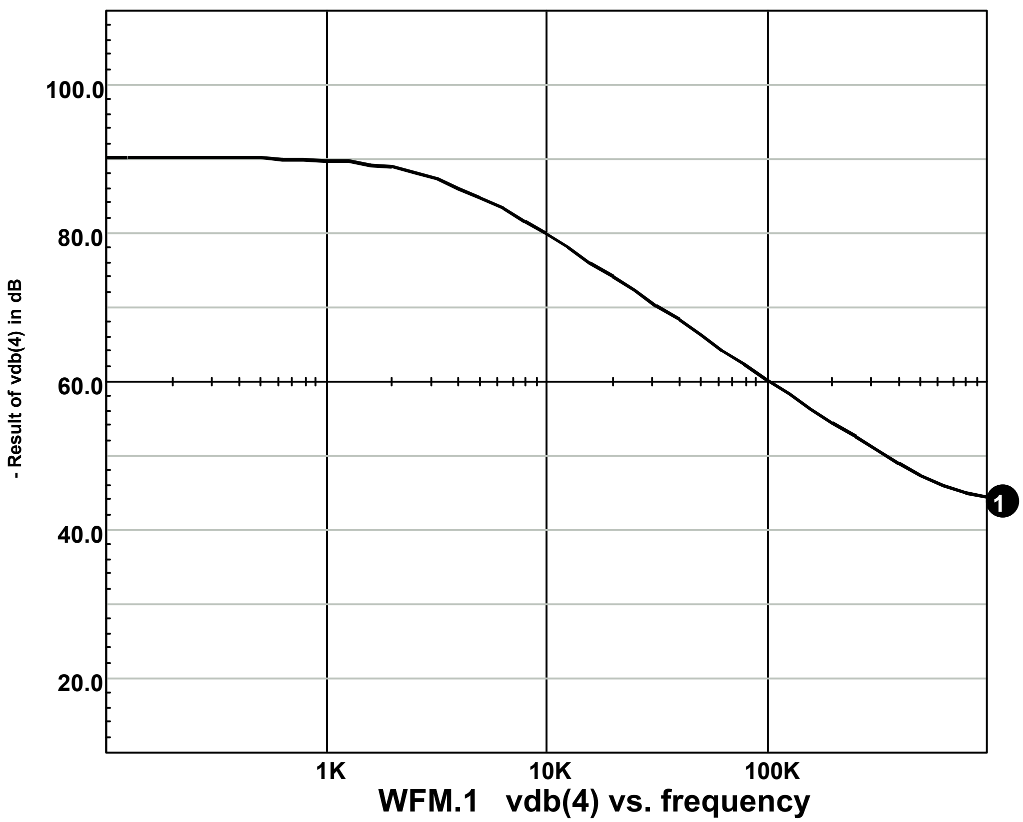
The following features and parameters are NOT modeled:

11. Divider, square, and square rooter performance (but, of course, the model can be operated in these modes).
12. Feedthrough.
13. Input signal voltage range, common mode.
14. Input voltage range vs. supply voltage.
15. Power supply rejection.
16. Slew rate (but the model's slew rate performance is shown for reference).

5.4.5 SPICE Simulations and Analyses

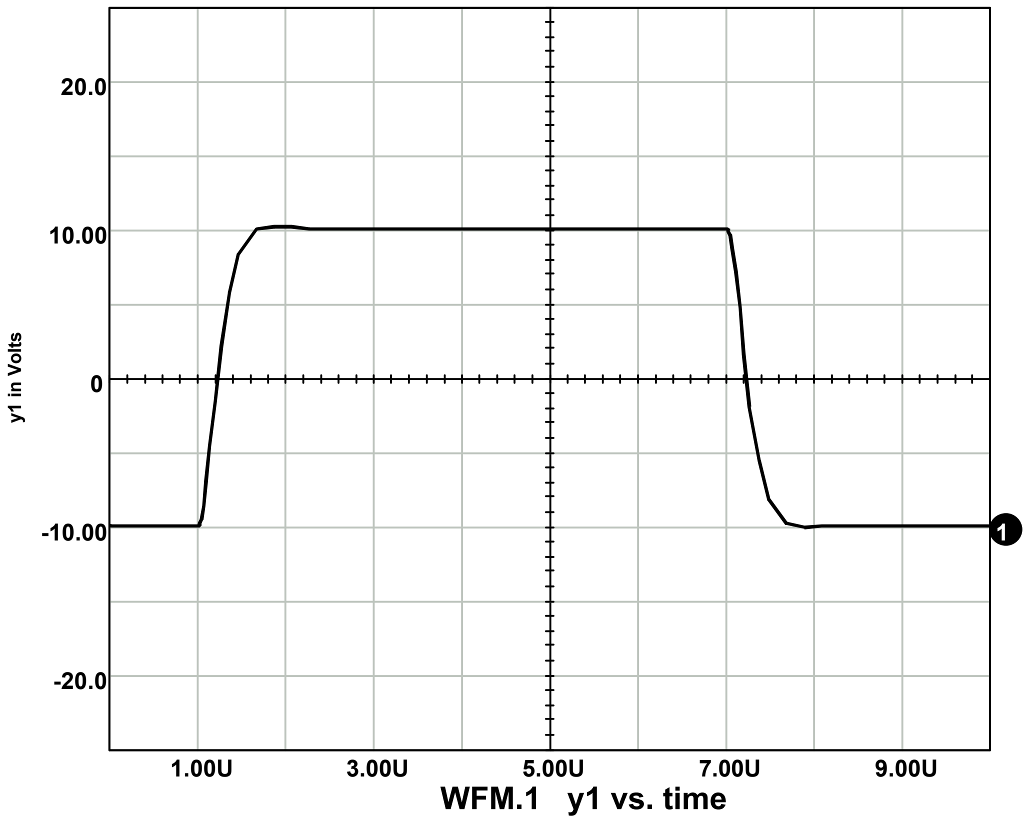
The model was simulated and the results were compared to the manufacturer's data sheet. The SPICE simulation results are shown below:

5.4.5.1 Common Mode Rejection



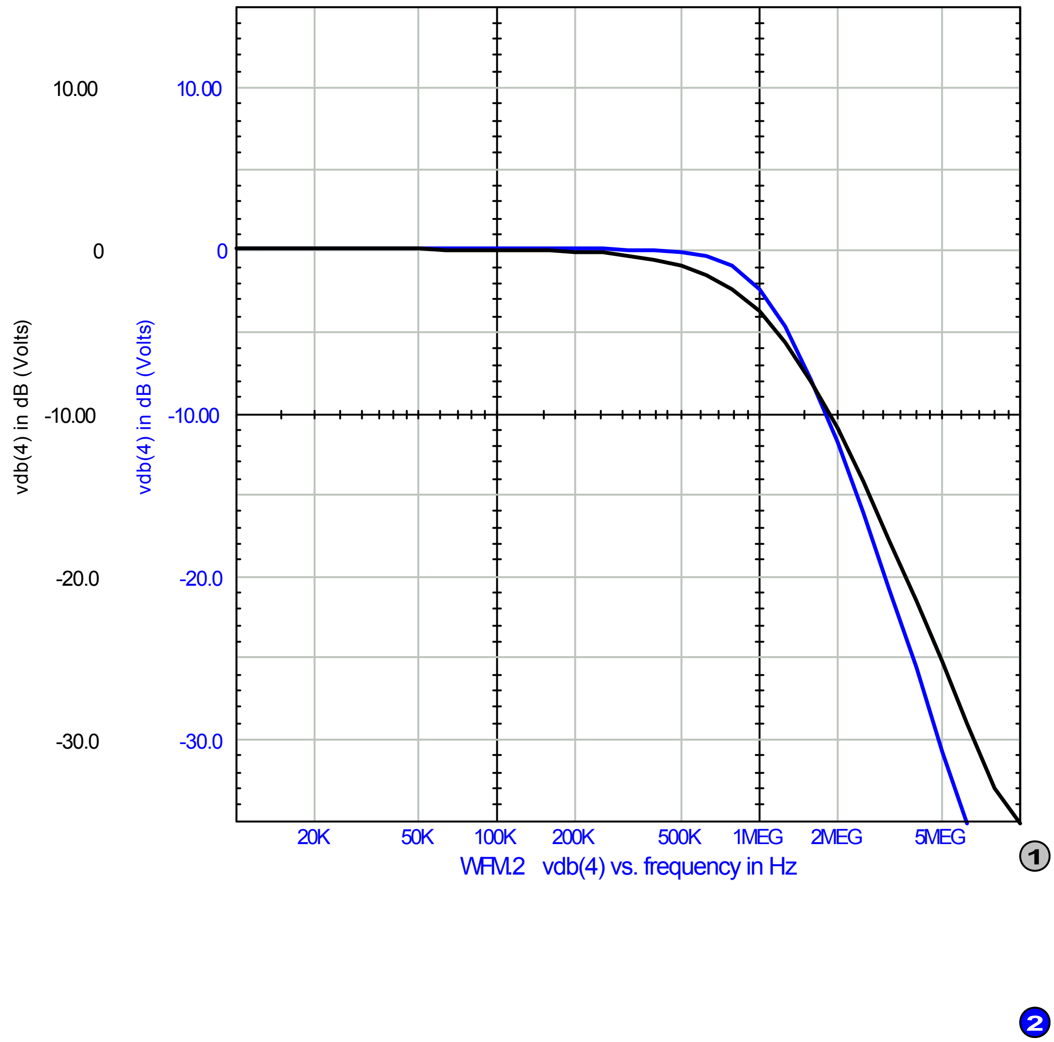
SPICE Waveform of common mode rejection

5.4.5.2 Slew Rate



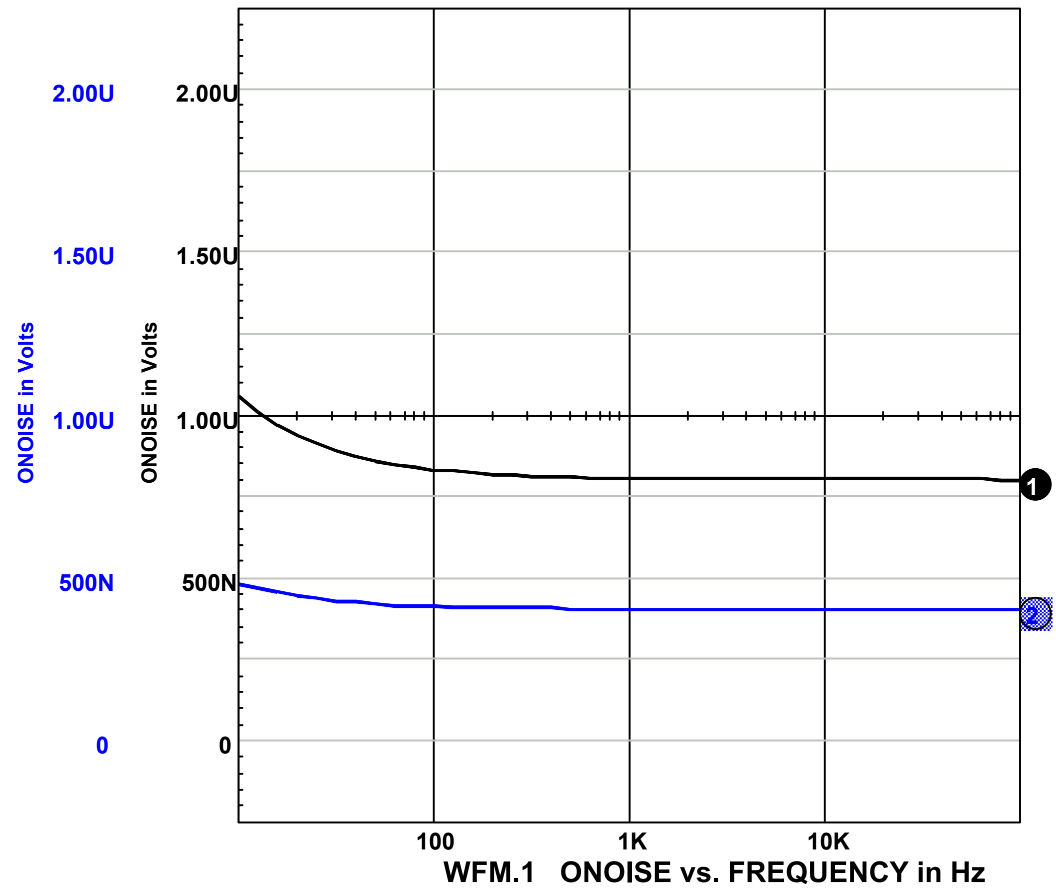
SPICE Waveform of slew rate

5.4.5.3 Frequency response



SPICE Waveforms of frequency response

5.4.5.4 Noise



SPICE Waveforms Noise spectral density (RTO)

5.4.5.5 DC Characteristics

The simulation results for these parameters are summarized in table 5.4.1.

5.4.5.5 Worst Case and End-of-Life Characteristics

Data for Worst Case and End-of-Life modeling is included in the attached file, AD534TWC.XLS.

5.4.7 Conclusions and Recommendations

The SPICE simulation results are summarized in table 5.4.1 and are within the manufacturer's electrical specifications.

Notes for Table 5.4.1:

1- Frequency response is modeled to agree with fig. 22 of the manufacturer's data sheet, which shows a small signal bandwidth of 0.87 MHz rather than 1 MHz.

2- Slew rate and settling time are not modeled. For reference, the model's performance is shown.

3- Input bias current is modeled to agree with fig. 17 of the manufacturer's data sheet, which shows 425nA rather than 800nA. Input offset current is scaled down by the same ratio.

Table 5.4.1 AD534T SPICE Model - Summary of Simulation Results

Unless otherwise specified, TA = +25C, +/- VS = 15V, RL = 2K

Parameter	Typ Spec	SPICE	UNITS
MULTIPLIER PERFORMANCE			
Scale Factor Error	0.1	0.1	%
Temperature Coefficient of Scaling Voltage	0.005 max	0.005	%
Nonlinearity, X (X 20 V p-p, Y = 10 V)	0.2	0.2	%
Nonlinearity, Y (Y 20 V p-p, X = 10 V)	0.1	0.1	%
Output Offset Voltage	2	2	mV
Output Offset Voltage Drift	100	100	uV/C
DYNAMICS			
Small Signal BW (1)	1	0.87	MHz
Slew Rate (Vout = 20Vp-p) (2)	20	35	V/us
(CL=1000pF)	20	29	V/us
Settling Time (to 1%, Vout = 20 Vp-p) (2)	2	<1	us
(CL=1000pF)	2	1.2	us
NOISE (RTO)	0.8	0.8	uV/sqrt(Hz)
Noise spectral density (SF=10V)	0.4	0.4	uV/sqrt(Hz)
(SF=3V)			
OUTPUT			
Output Voltage Swing	Per fig. 16	Per fig. 16	
Output Impedance (f <=1 kHz)	0.1	0.076	Ohm
Output Short Circuit Current (RL = 0)	30	30	mA
Amplifier Open Loop Gain (f = 50 Hz)	70	70	dB

Table 5.4.1 AD534T - Summary of Simulation Results (cont.)

Parameter	Typ Spec	SPICE	UNITS
INPUT AMPLIFIERS (X, Y and Z)			
Signal Voltage Range (Differential)	1.25 x SF	1.25 x SF	V
Offset Voltage, X, Y	2	2	MV
Offset Voltage Drift, X, Y	150	150	uV/C
Offset Voltage, Z	2	2	MV
Offset Voltage Drift, Z	300 max	150	uV/C
CMRR	90	90	DB
Bias Current (3)	0.8	0.425	UA
Offset Current (3)	0.1	0.053	UA
Offset Current Drift	Per fig. 17	Per fig. 17	
Differential Resistance	10	10	Mohm
POWER SUPPLY SPECIFICATIONS			
Supply Current, Quiescent	4	4	MA