5.4 AD524S Instrumentation Amplifier

5.4.1 Scope

The purpose of this analysis is to model the Analog Devices AD524S Instrumentation Amplifier.

Analysis:	**Amplifier modeling**
Last Rev Date:	**1/18/2002**
Publication Number:	**AD524_e.pdf**
Revision:	**1999 - Rev E**
SPICE File	**AD524S.CIR**

5.4.2 Functional Description

The AD524S is an instrumentation amplifier with programmable gain. No external components are required for the pin-programmable gains of 1, 10, 100, and 1000. Other gains can be set by adding a single external resistor. A differential input is provided. The output amplifier feedback loops are connected externally, allowing for an additional offset voltage input and remote output sensing for increased accuracy.

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 gain, input and output offset voltage, input Bias and Offset Current.
2. Temperature coefficient of input bias and offset currents cannot all be equal to the specified value of 100pA/C simultaneously, so I bias of one input is set to 100pA/C, I offset is set to 50pa/C and I bias of the second output is set to 50pA/C. This can be adjusted as appropriate in the worst case analysis.
3. A typical value for input offset current is not specified by the manufacturer, but is chosen to be proportional to input bias current in the same proportion as the max values.
4. Output voltage swing vs. supply voltage is modeled to agree with fig. 2 of the manufacturer's data sheet.
5. Input voltage range vs. supply voltage is modeled to agree with fig. 1 of the manufacturer's data sheet. Neither differential nor common mode is specifically modeled, but, rather, both inputs are independently limited.
6. Common mode rejection vs. frequency is modeled to approximately agree with fig. 10 of the manufacturer's data sheet. Note that it is specified as RTI.
7. Frequency response is modeled to agree with fig. 9 of the manufacturer's data sheet. Bandwidth is most accurate at G=1 and G=1000, but is only approximate at G=10 and 100.
8. Voltage noise spectral density (RTI) vs. gain is modeled to agree with fig. 15 of the manufacturer's data sheet.

9. Power dissipation is modeled by the correct simulation of quiescent supply current. Output load current is correctly steered to either the positive or negative power supply as applicable.
10. Typical values for gain error are not specified, thus they are set to zero for this model, but will be modeled in accordance with the maximum values in the worst case analysis.
11. Typical values for input and output offset voltage are not specified, thus arbitrary values, well less than the maximums are used for this model.

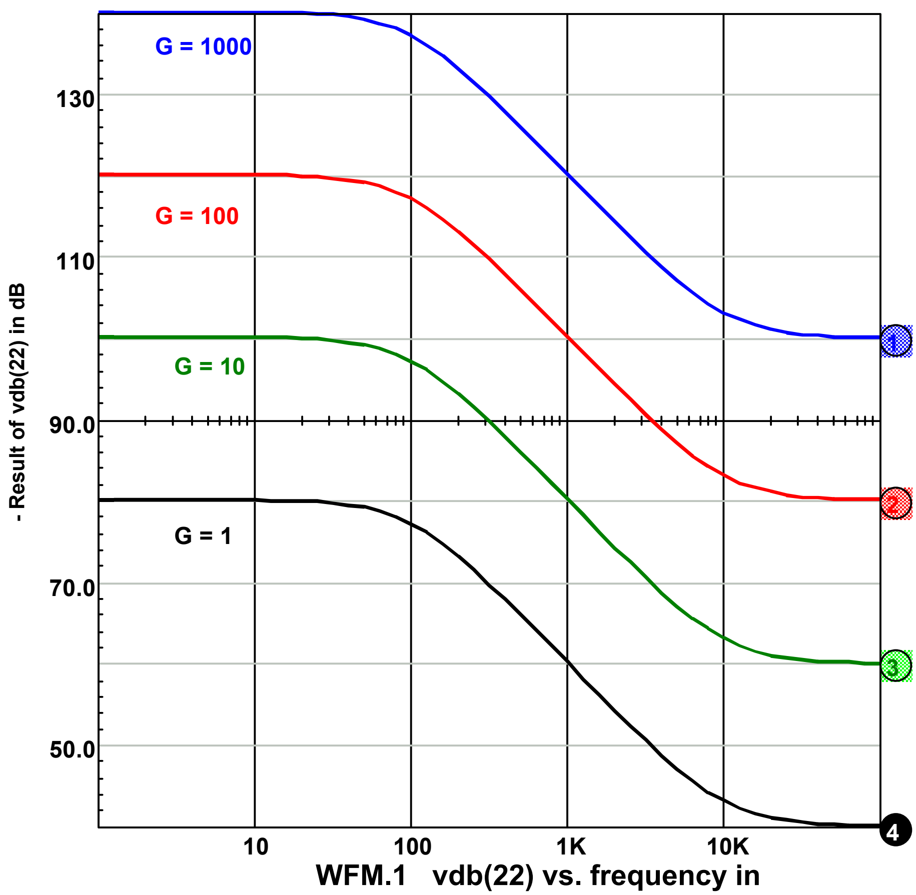
The following features and parameters are NOT modeled:

12. Power supply rejection.
13. Slew rate and settling time (but the model's performance is shown for reference).

5.4.5 SPICE Simulations and Analyses

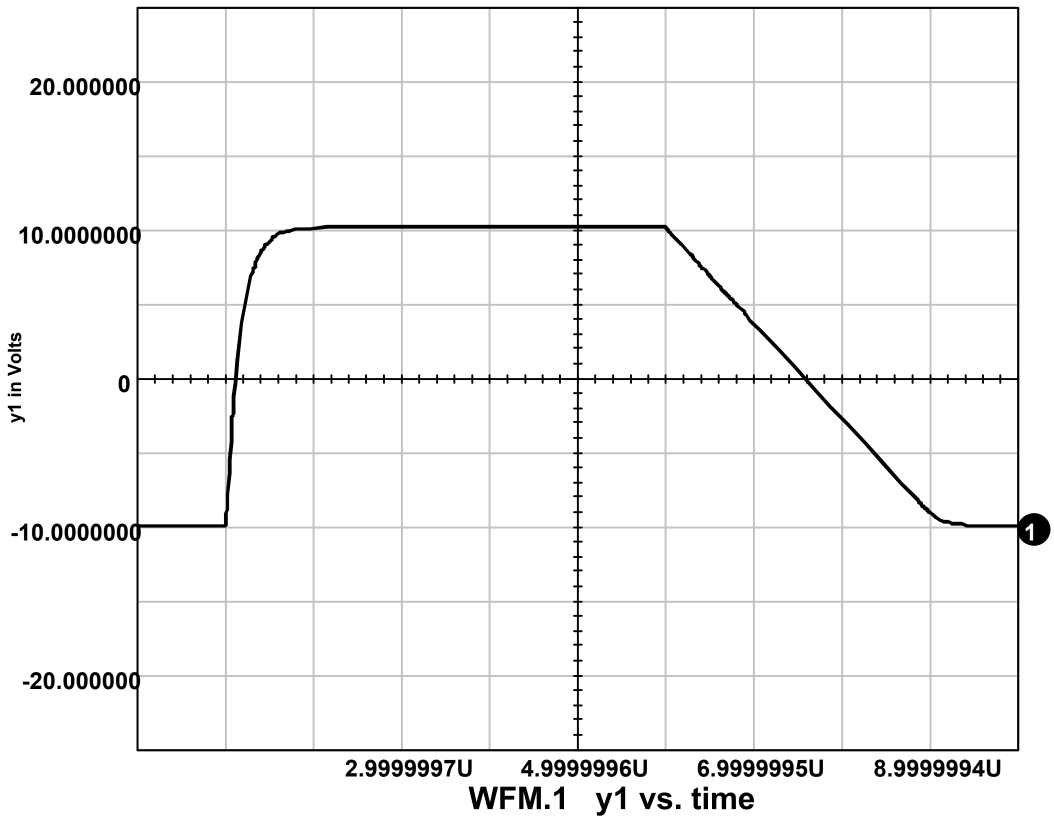
The model was simulated and the results were compared to the manufacturer's data sheet. The Spice simulation results are shown below:

5.4.5.1 Common Mode Rejection



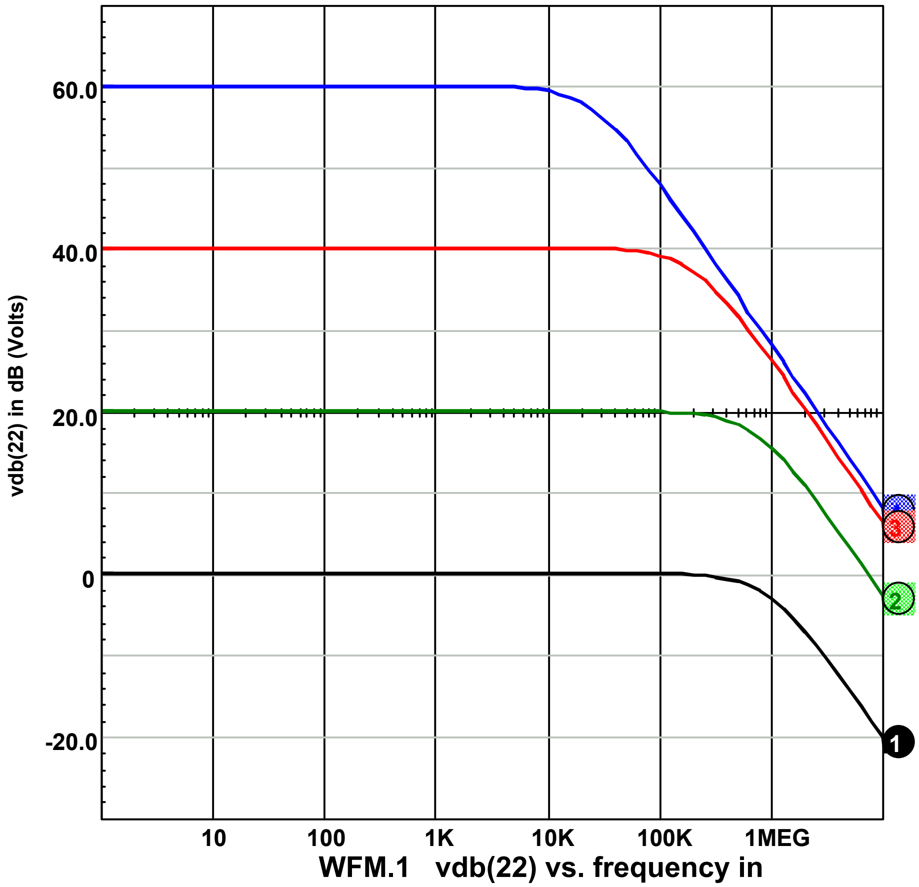
SPICE Waveform of common mode rejection

5.4.5.2 Slew Rate



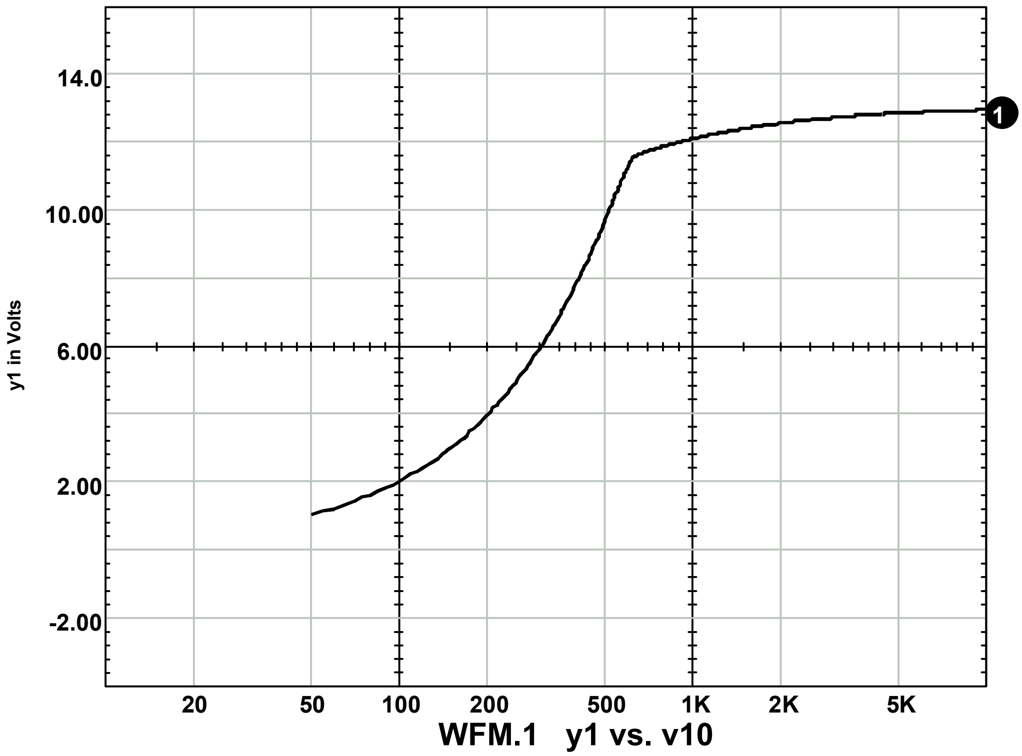
SPICE Waveform of slew rate

5.4.5.3 Frequency response



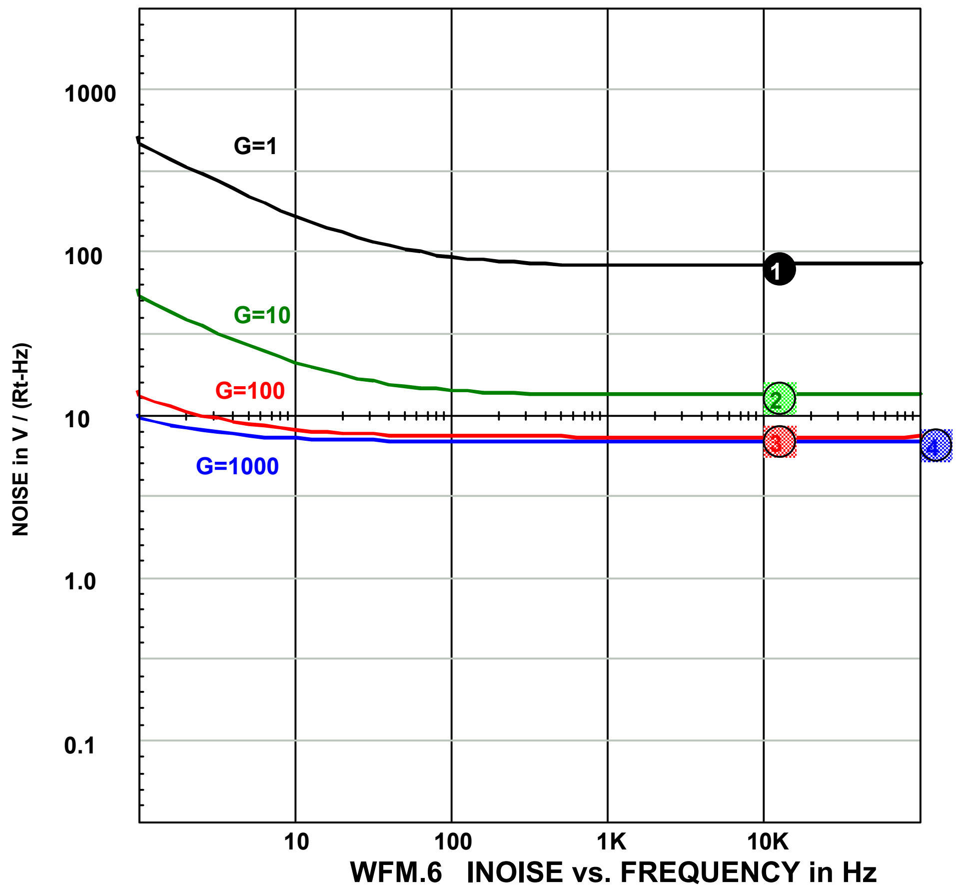
SPICE Waveforms of frequency response

5.4.5.4 Output voltage swing



SPICE Waveform of output voltage swing vs. load resistance

5.4.5.5 Noise



SPICE Waveforms of voltage noise spectral density (RTI)

5.4.5.6 DC Characteristics

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

5.4.5.7 Worst Case and End-of-Life Characteristics

Data for Worst Case and End-of-Life modeling is included in the attached file, AD524SWC.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- Typical values for gain error are not specified, thus they are set to zero for this model, but will be modeled in accordance with the maximum values in the worst case analysis.

2- Typical values for input and output offset voltage are not specified, thus arbitrary values, well less than the maximums are used for this model.

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

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
GAIN			
Gain Error (1), G = 1	0.05 max	0	%
G = 10	0.25 max	0	%
G = 100	0.5 max	0	%
G = 1000	2.0 max	0	%
Nonlinearity, G = 1, 10, 100, 1000	0.01 max	0.01	%
Gain vs. Temperature, G = 1	5 max	5	ppm/C
G = 10	10 max	10	ppm/C
G = 100	25 max	25	ppm/C
G = 1000	50 max	50	ppm/C
VOLTAGE OFFSET			
Input Offset Voltage (2)	100 max	15	uV
vs. Temperature	2.0 max	2.0	uV/C
Output Offset Voltage (2)	3.0 max	1.0	mV
vs. Temperature	50 max	50	uV/C
INPUT CURRENT			
Input Bias Current	10	10	nA
vs. Temperature, IN+	100	100	pA/C
IN-	100	50	pA/C
Input Offset Current	35 max	7	nA
vs. Temperature	100	50	pA/C
INPUT			
Input Voltage Range	12.5	12.5	V
vs. supply	Per fig. 1	Per fig. 1	V
CMRR	Per fig. 10	Per fig. 10	dB
G = 1	80	80	dB
G = 10	100	100	dB
G = 100	120	120	dB
G = 1000	130	140	dB

Table 5.4.1 AD524S - Summary of Simulation Results (cont.)

Parameter	Typ Spec	SPICE	UNITS
OUTPUT RATING			
Output Voltage Swing, RL = 2kOhms	12.5	12.5	V
vs. supply	Per fig. 2	Per fig. 2	V
vs. load	Per fig. 3	Per fig. 3	V
DYNAMIC RESPONSE			
Small Signal BW, -3dB, G = 1	1	1.00	MHz
G = 10	400	733	kHz
G = 100	150	207	kHz
G = 1000	25	25.3	kHz
Slew Rate (3) (Vout = 20Vp-p), t rise	5.0	41	V/us
t fall	5.0	6.5	V/us
Settling Time (3) (to 0.01%, Vout = 20 Vp-p)			
G = 1	15	61	us
G = 10	15	8.3	us
G = 100	15	4.9	us
G = 1000	75	57	us
NOISE			
Voltage noise spectral density, @ 1 kHz			
RTI	7	6.8	nV/sqrt(Hz)
SENSE INPUT			
R IN	20	20	kOhms
REFERENCE INPUT			
R IN	20	20	kOhms
POWER SUPPLY			
Quiescent current	3.5	3.5	mA