Simulation of the Silicon Pads Summation Scheme

Using LTSPICE (www.linear.com).

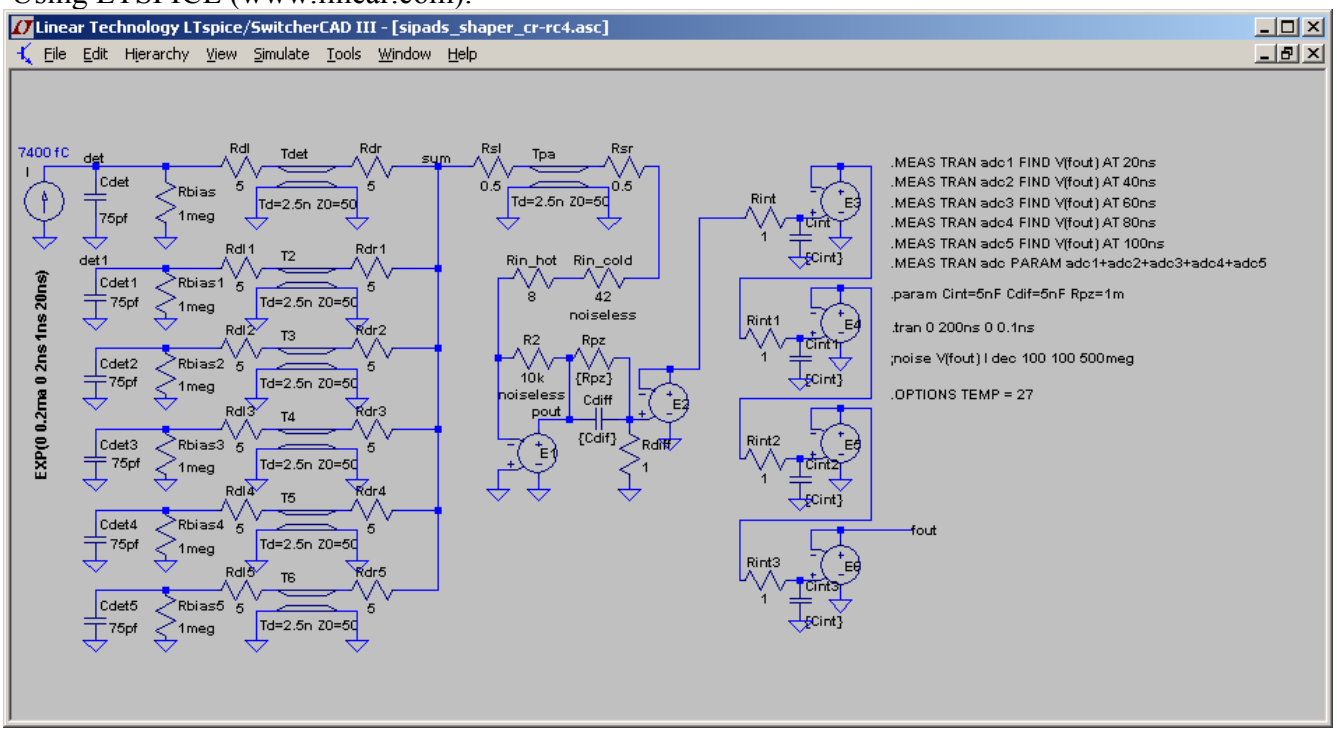

Fig. 1. Simulation schematics.

Sensors lines

I – current source, injected charge = 7400 fC
Cdet – bulk capacitance of the pad.
Rbias – bias resistor of the pad.
Tdet, Rdl, Rdr – transmission line from detector to summation point, Z0=50oh, R=10ohm.
Tpa, Rsl, Rsr – transmission line from summation point to preamp.
Two major options were simulated.

1) Z0=50ohm, Rin=50ohm comprising 42ohm of noiseless (cold) resistance and 8 ohm of noisy (hot) resistance.
2) Z0=18ohm, Rin=8ohm, noisy. A realistically achievable line. For such a line the Rsr+Rsl could be as low as 0.2ohm.

Preamp

E1, R2 – current amplifier with G=10k

CR-RC(4) shaper

E2, Cdiff, Rdiff, Rpz – differentiating cascade, Rpz – for pole-zero cancellation.
E3, E4, E5, E6 – integrating cascades

Transmission line and RintCint.
The transmission line Tpa significantly affects the frequency response of the system. Therefore to compare circuits with different Tpa impedance I used to adjust the Cint in such a way that the shape of the output pulse at 'fout' would be similar. Numerical criterion is the FWHM of the V(fout).

Signal to noise ratio.
I used three measures of the output signal:

1) ADC – sum of V(fout) at 5 points: 20ns, 40ns, 60ns, 80ns and 100ns. This resembles sampling by 50 MSPS ADC.
2) RMS – RMS of the V(fout) in 0-200ns window
3) Average – average of the V(fout) over 0-200ns window

The noise is always measured as RMS of V(fout) in bandwidth 100Hz – 500MHz

Summary table

	Tpa [ns]	Z0pa [ohm]	Rin [ohn	Cint [nF]	Cdif [nF]	Rpz [nF]	Amax [mV]	Tmax [ns]	FWH	ADC [mV]	RMS [mV]	Average [mV]	RMS Nc [mV]	S/N ADC	S/N RMS	S/N Average	Figu
1	2.5	8	8							-1840	369	-190	7.100	259.2	52.0	26.8	2
2	2.5	8	8	5	5	0	-822	40		-1839	324	-190	0.965	1905.7	335.8	196.9	3
2b	2.5	8	8	15		0	-455	76		-1393	245	-188	0.255	5462.7	960.8	737.3	
3	2.5	8	8	5	5	4				-379	83.4	-39	0.445	851.7	187.4	87.6	4
4	2.5	50	50	5	5	4				-331	53	-37.5	0.102	3245.1	519.6	367.6	6
5	2.5	50	50	5		0	-448	55.9	75	-1478	238	-185	0.264	5598.5	901.5	700.8	7
6	2.5	50	50	10		0	-384	78.9		222	222	-181.5	0.161	1378.9	1378.9	1127.3	
7	2.5	50	50	20		0	-283	119		-599.4	188.5	-159.5	0.087	3248.8	1727.0	1396.3	
8	2.5	50	50	30		0	-221	152		-282	149.9	-121.2	0.057	4982.3	2648.4	2141.3	
9	0.1	50	50	5		0		60		-1505	238	-186	0.259	5810.8	918.9	718.1	
10	0.1	18	8	10		0				-1728			0.740	2335.1	0.0	0.0	
11	2.5	18	8	5		0	-902	41		-1849	338	-190	0.945	1956.6	357.7	201.1	8
12	2.5	18	8	10		0	-624	58.5	56.2	-1730	285	-190	0.422	4099.5	675.4	450.2	
13	2.5	18	8	15		0	-468	74.9	80	-1413	249	-188.1	0.235	6012.8	1059.6	800.4	9
14	2.5	18	8	20		0	-373	91.5		-1051	222	-182	0.157	6694.3	1414.0	1159.2	
15	2.5	18	8	30		0	-263	124		-539	180	-152	0.086	6267.4	2093.0	1767.4	

The two best cases are rows 5 and 15. Both have similar S/N and 'identical' shape of the output pulse.

1) Row 5: Tpa with impedance 50ohm, preamp with input resistance 50ohm (42ohm cold and 8ohm hot), RintCint = 5ns.
2) Row 15: Tpa with impedance 18ohm, preamp with input hot resistance 8ohm, RintCint = 15ns.

The rows 6,7,8,14,15 have better S/N but they all deliver too long output pulse.

Figures

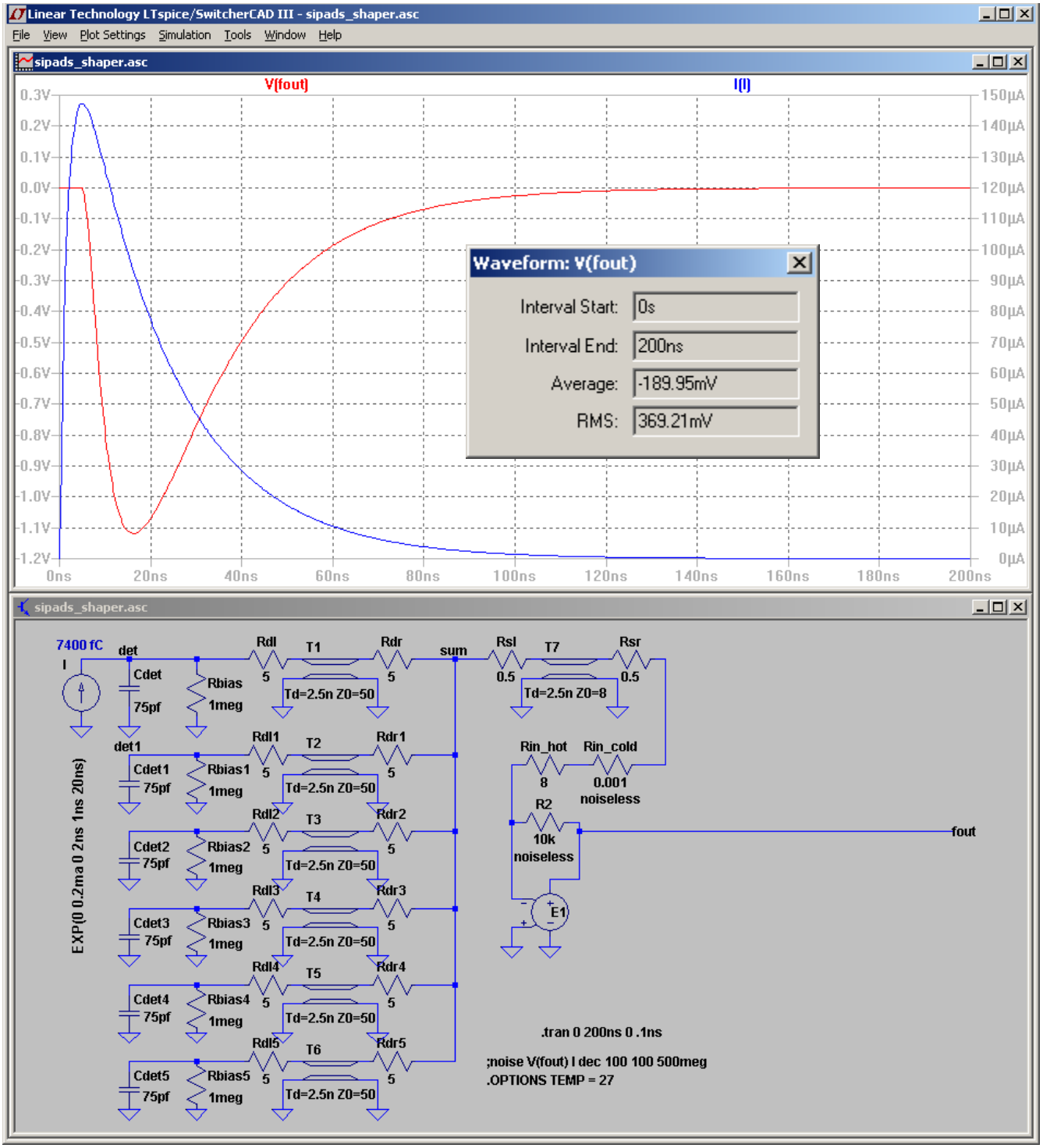

Fig.2a. Balanced Tpa, Z0=8 ohm, Rin=8ohm. No shaping. Transient analysis.
ADC = -1.854

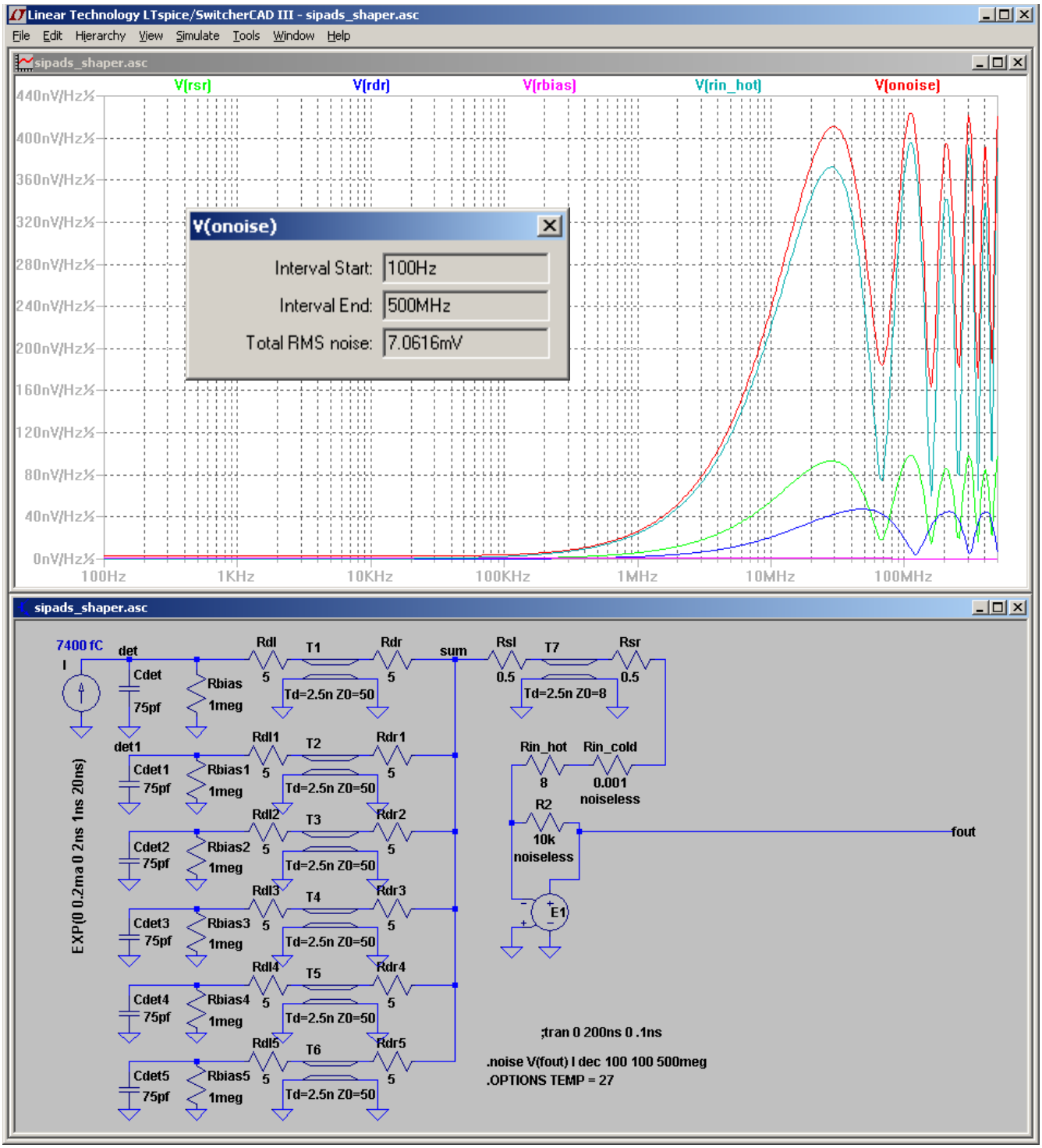

Fig 2b. Balanced Tpa, Z0=8 ohm, Rin=8ohm. No shaping. Noise spectrum.

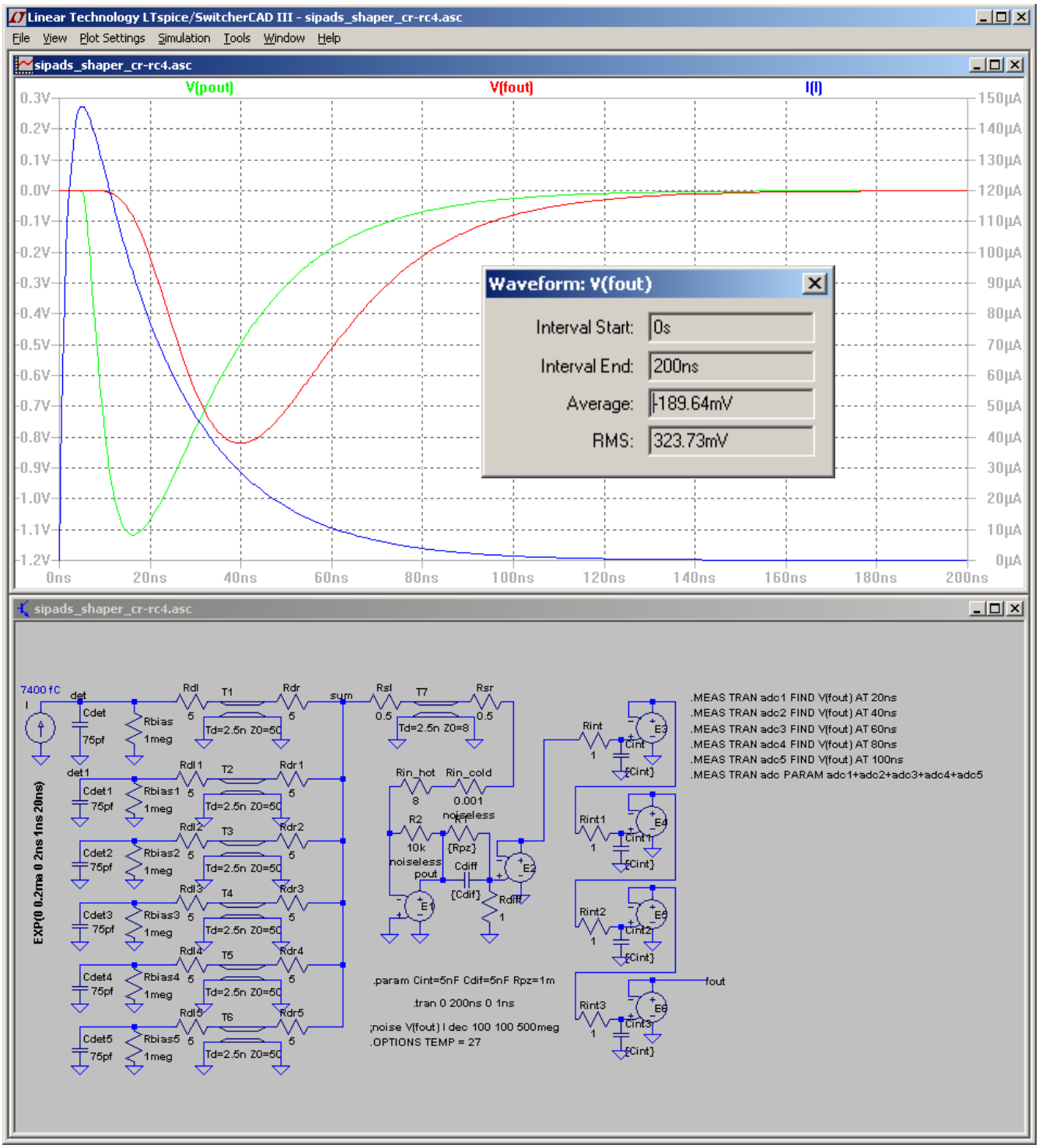

Fig. 3a. Balanced Tpa, Z0=8 ohm, Rin=8ohm. RC(4) shaping. Note that Cdif is shunted by Rpz=0.001ohm.

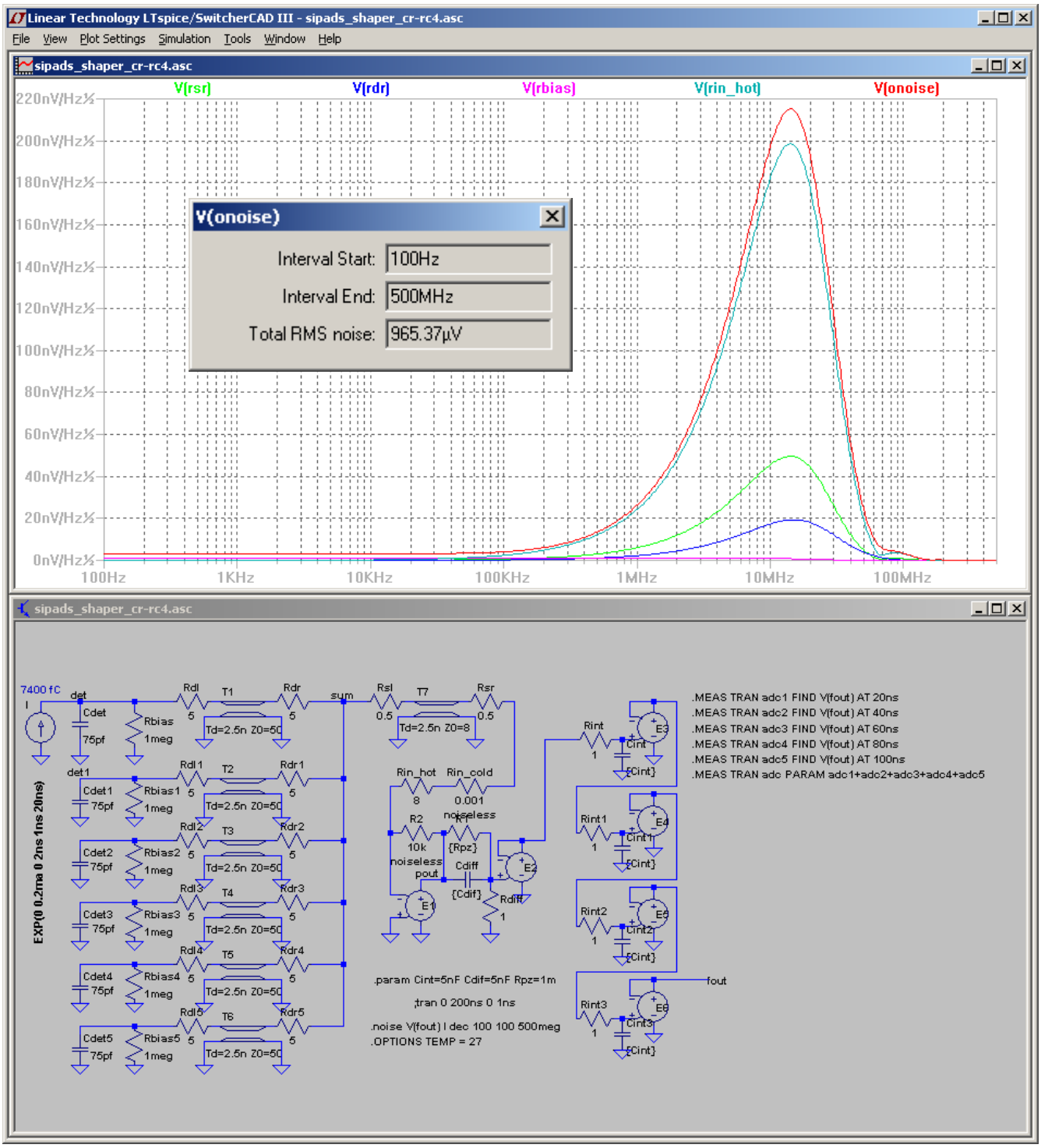

Fig. 3b. Balanced Tpa, Z0=8 ohm, Rin=8ohm. RC(4) shaping. Noise spectrum.

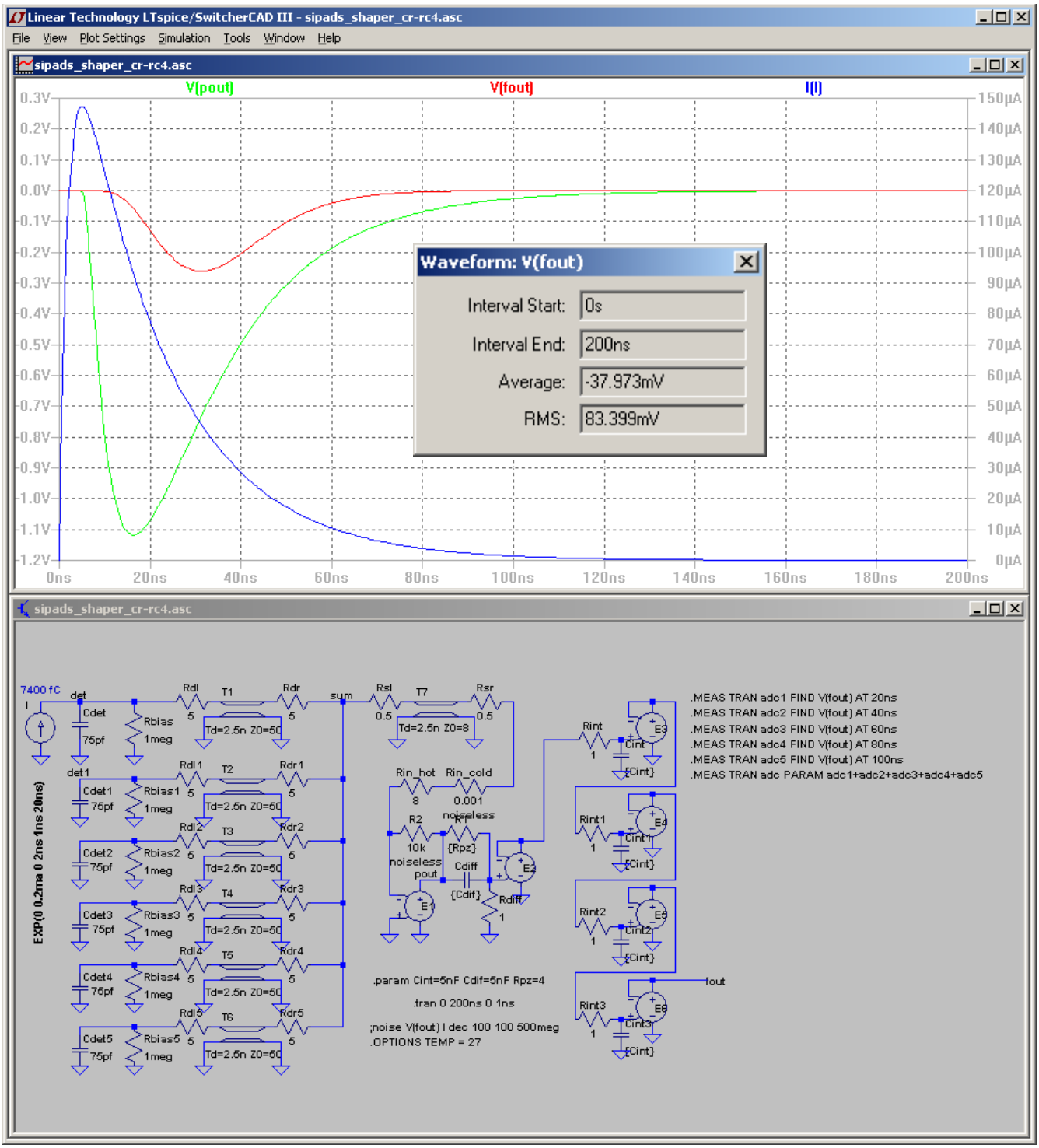

Fig. 4A. Balanced Tpa, Z0=8 ohm, Rin=8ohm. CR-RC(4) shaping with pole-zero cancellation.

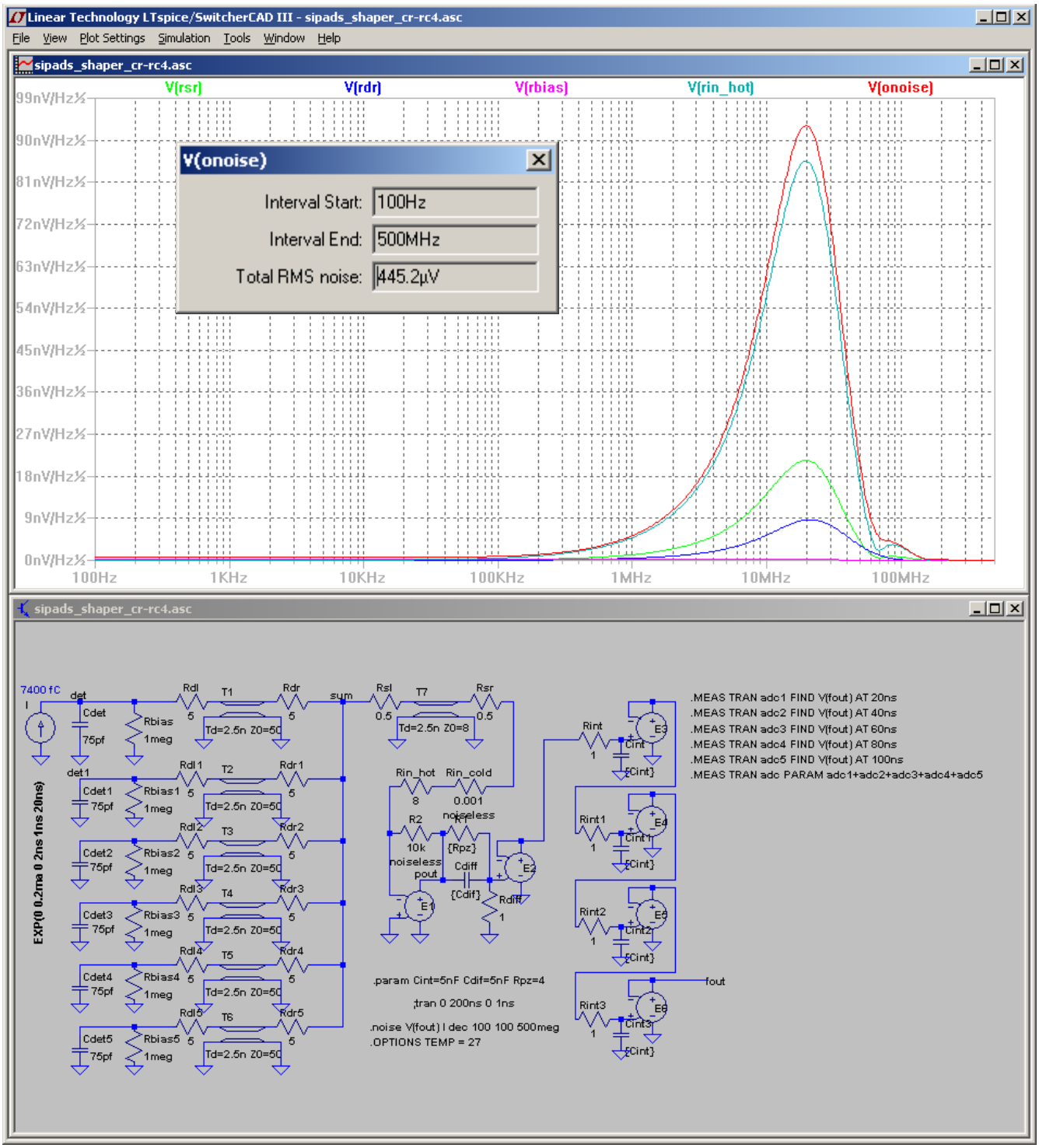

Fig 4B. Balanced Tpa, Z0=8 ohm, Rin=8ohm. CR-RC(4) shaping with pole-zero cancellation.

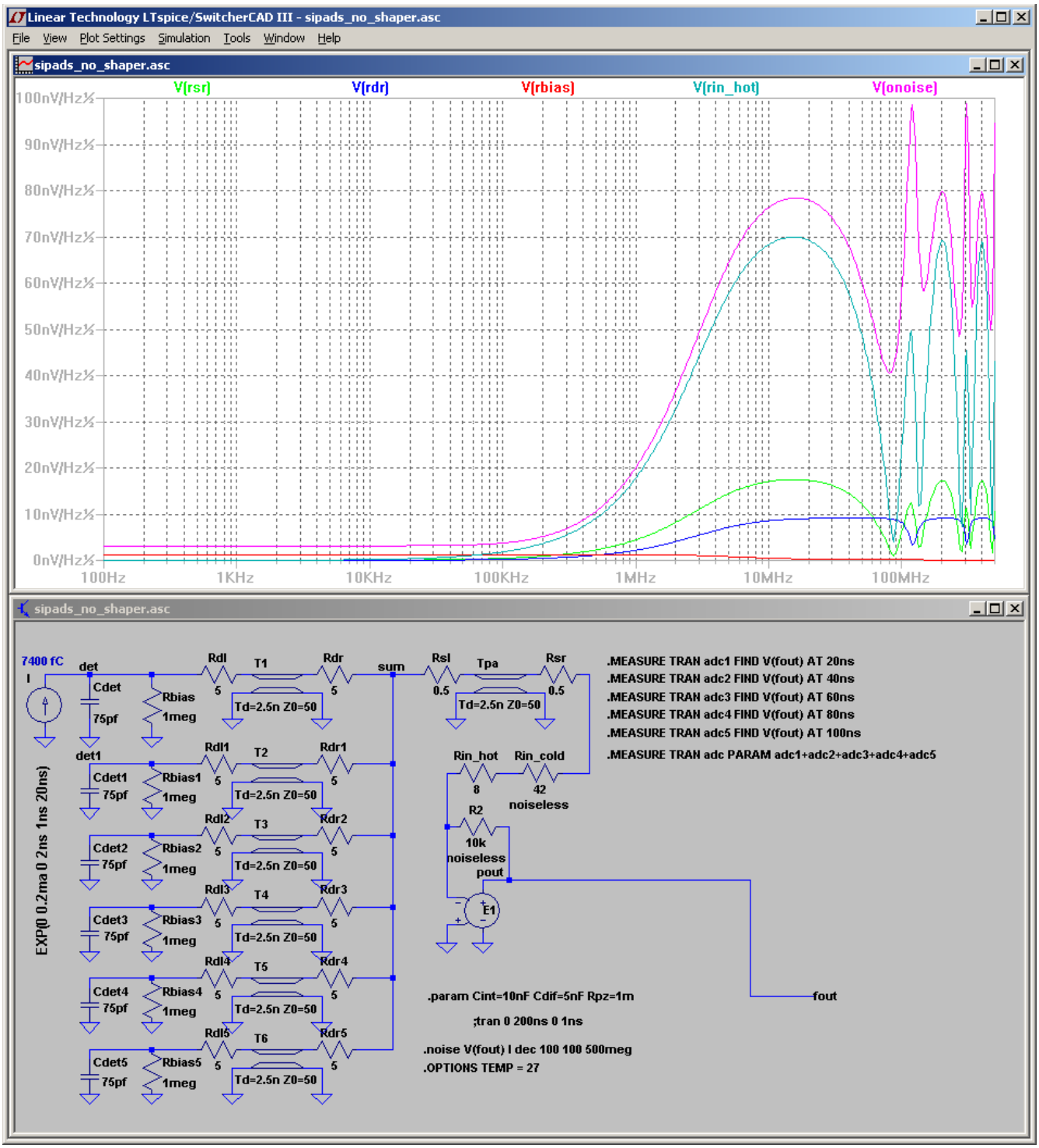

Fig. 5. Z0(Tpa) = 50ohm, Rin=50ohm, no shaping. Noise spectrum.

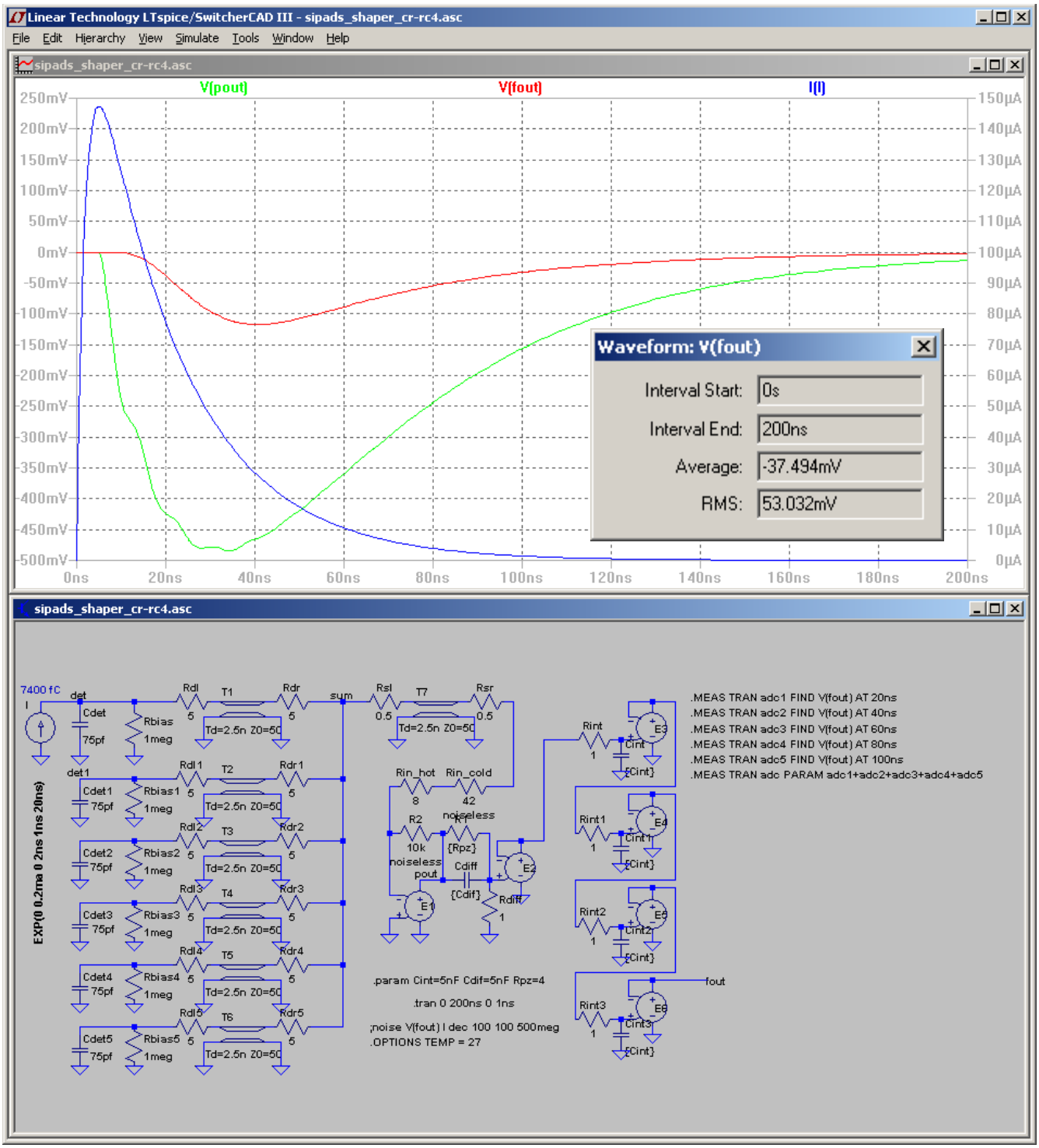

Fig 6A. Z0(Tpa)=50 ohm, Rin=50ohm. CR-RC(4) shaping with pole-zero cancellation.

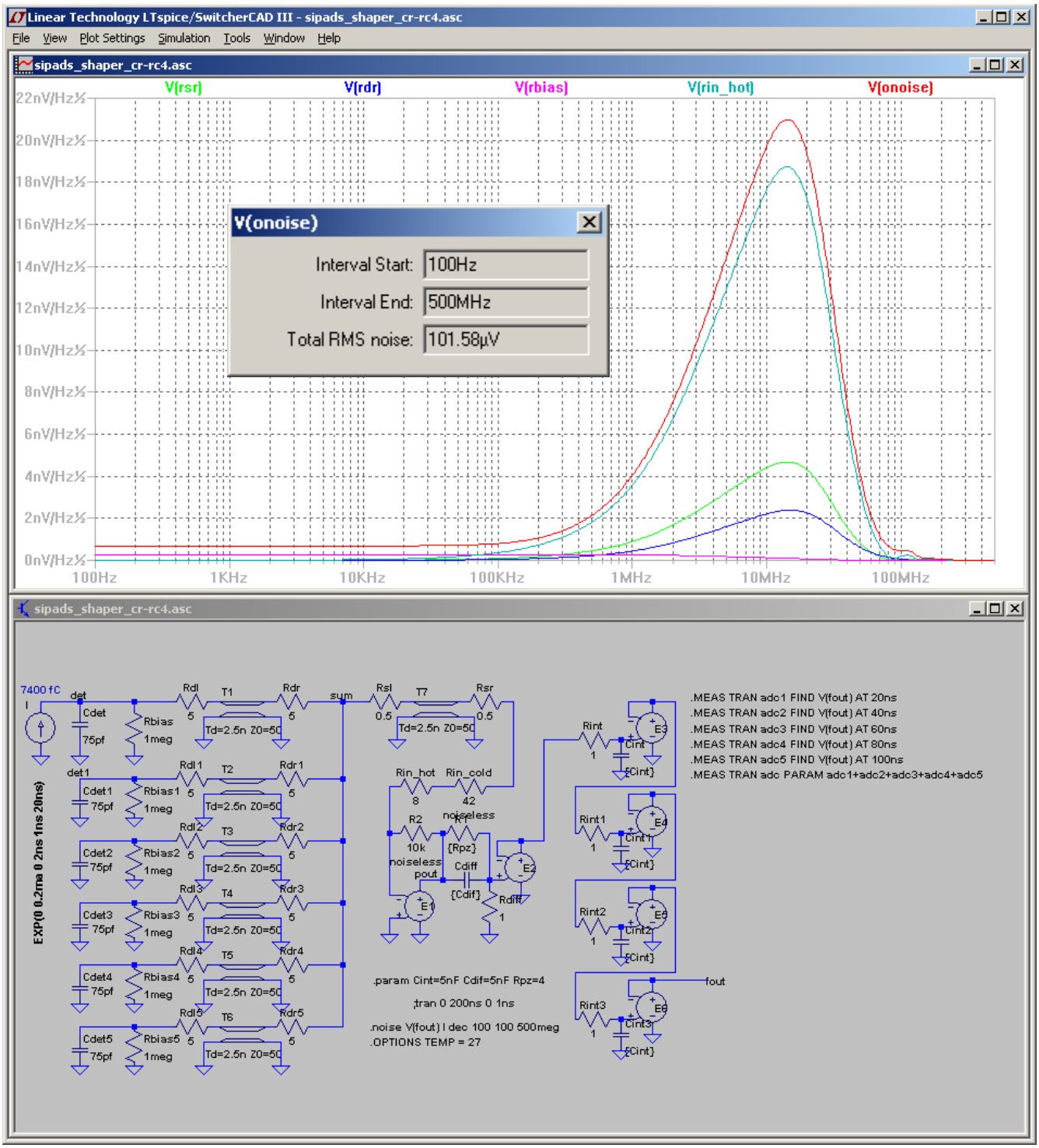

Fig. 6B. Z0(Tpa)=50 ohm, Rin=50ohm. CR-RC(4) shaping with pole-zero cancellation.

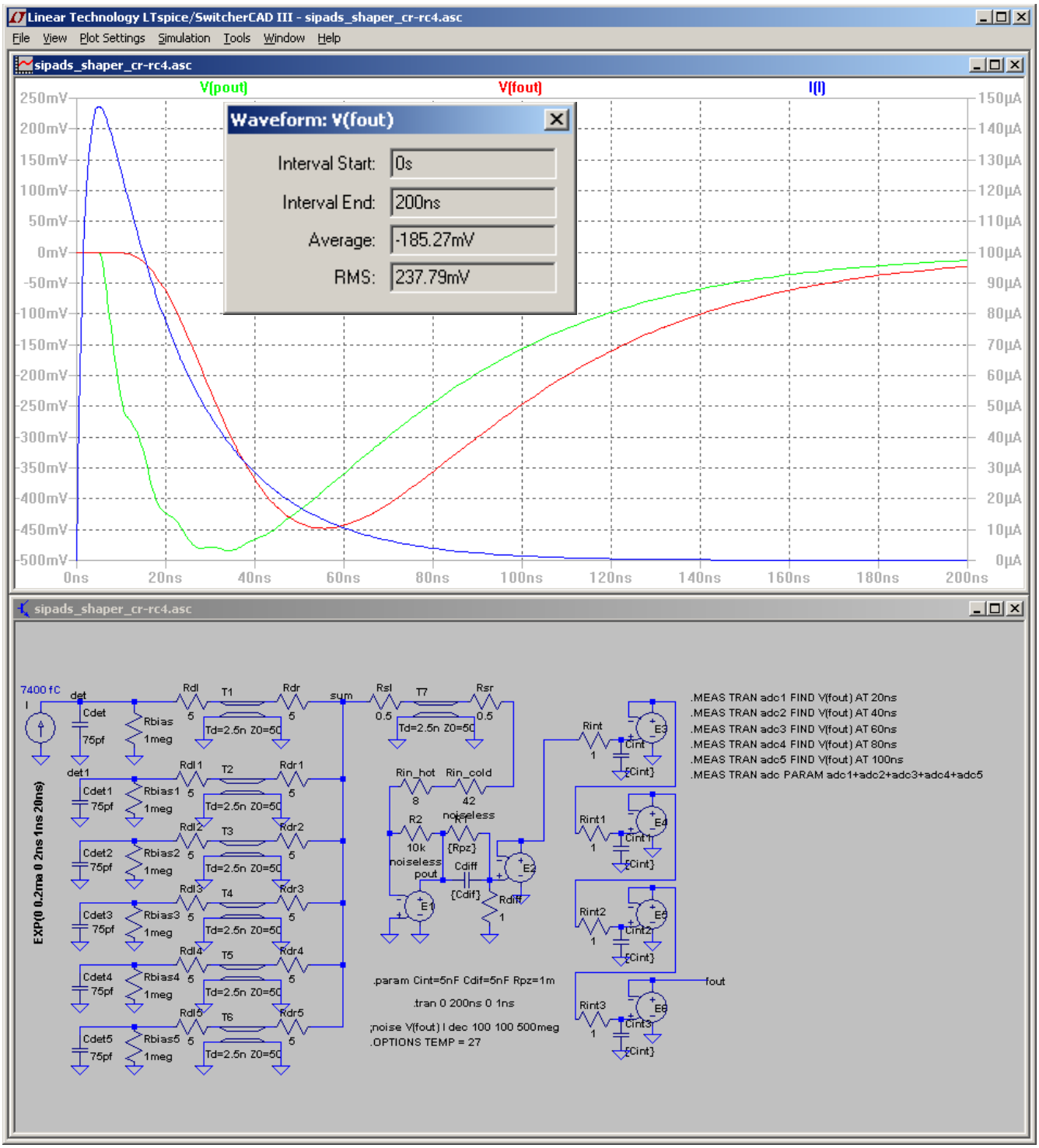

Fig. 7A. Z0(Tpa)=50 ohm, Rin=50ohm. RC(4) shaping.

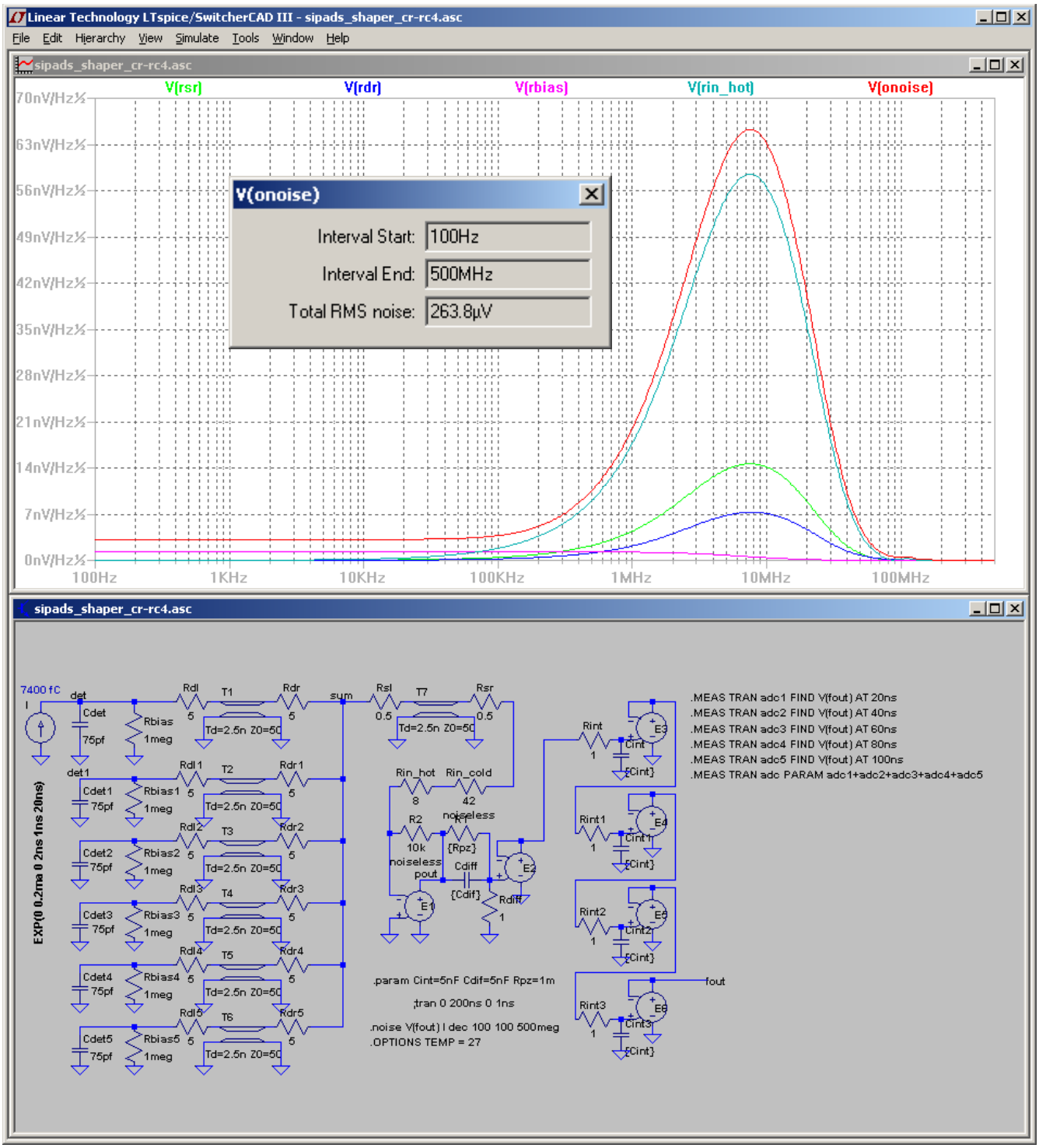

Fig. 7B. Z0(Tpa)=50 ohm, Rin=50ohm. RC(4) shaping.

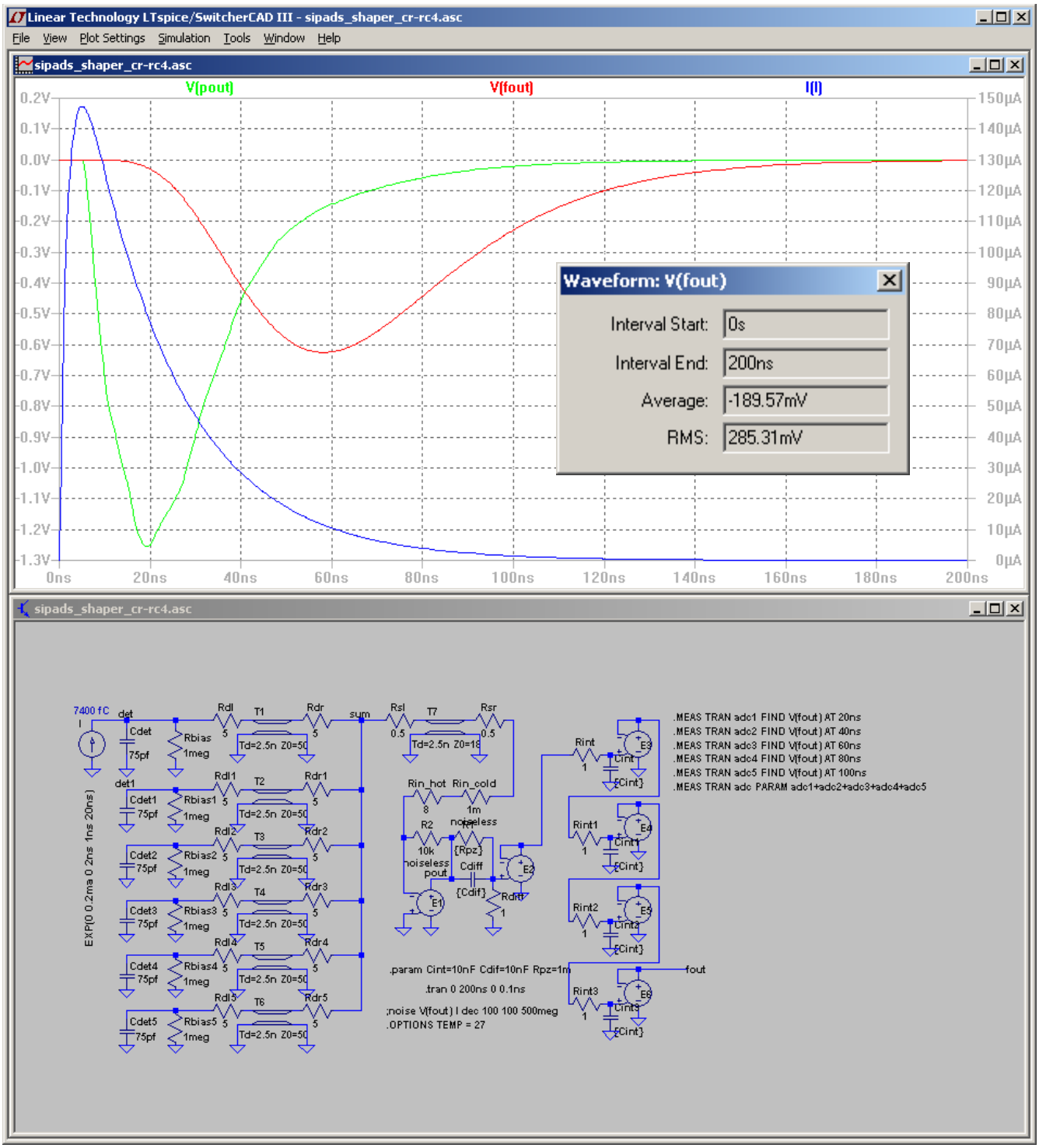

Fig.8A. Z0(Tpa)=18 ohm, Rin=8ohm. RC(4) shaping.

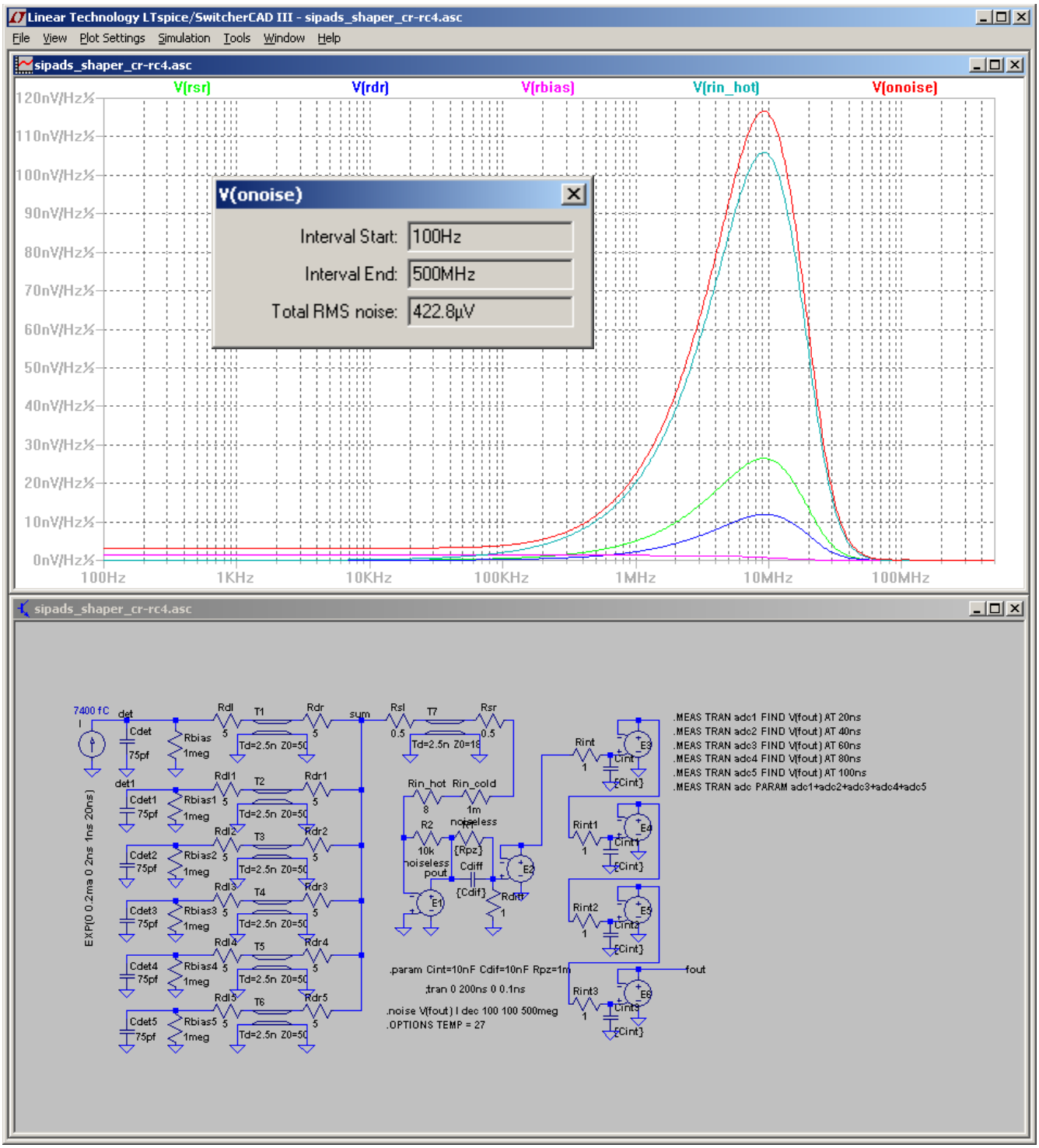

Fig.8B. Z0(Tpa)=18 ohm, Rin=8ohm. RC(4) shaping.

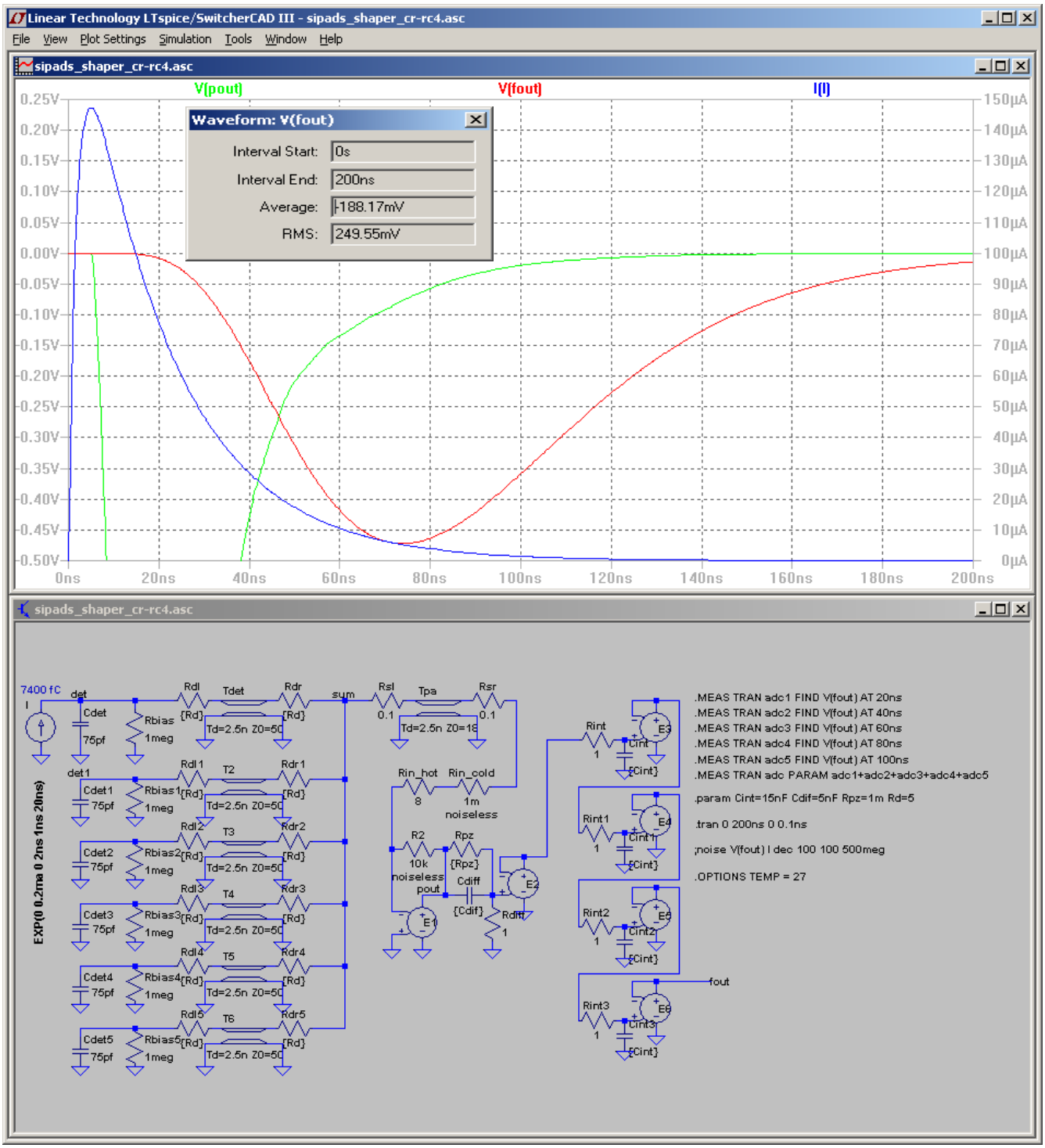
Linear Technology LTspice/SwitcherCAD III - sipads_shaper_cr-rc4.asc
File View Plot Settings Simulation Tools Window Help
sipads_shaper_cr-rc4.asc
V(pout)
V(fout)
I(I)
Waveform: V(fout)
Interval Start: 0s
Interval End: 200ns
Average: -188.17mV
RMS: 249.55mV
0.25V
0.20V
0.15V
0.10V
0.05V
0.00V
-0.05V
-0.10V
-0.15V
-0.20V
-0.25V
-0.30V
-0.35V
-0.40V
-0.45V
-0.50V
150µA
140µA
130µA
120µA
110µA
100µA
90µA
80µA
70µA
60µA
50µA
40µA
30µA
20µA
10µA
0µA
0ns
20ns
40ns
60ns
80ns
100ns
120ns
140ns
160ns
180ns
200ns
sipads_shaper_cr-rc4.asc
7400 fC
I
EXP(0 0.2ma 0 2ns 1ns 20ns)
det
Cdet
75pf
Rbias
1meg
Rdl
Tdet
Rdr
{Rd}
Td=2.5n Z0=50
sum
Rsl
Tpa
Rsr
0.1
Td=2.5n Z0=18
Rin_hot
Rin_cold
8
1m
noiseless
R2
10k
noiseless
pout
Rpz
{Rpz}
Cdiff
{Cdif}
Rdiff
1
E1
E2
Rint
Cint
{Cint}
E3
Rint1
E4
Rint2
E5
Rint3
E6
fout
.MEAS TRAN adc1 FIND V(fout) AT 20ns
.MEAS TRAN adc2 FIND V(fout) AT 40ns
.MEAS TRAN adc3 FIND V(fout) AT 60ns
.MEAS TRAN adc4 FIND V(fout) AT 80ns
.MEAS TRAN adc5 FIND V(fout) AT 100ns
.MEAS TRAN adc PARAM adc1+adc2+adc3+adc4+adc5
.param Cint=15nF Cdif=5nF Rpz=1m Rd=5
.tran 0 200ns 0 0.1ns
;noise V(fout) I dec 100 100 500meg
.OPTIONS TEMP = 27

Fig. 9A.

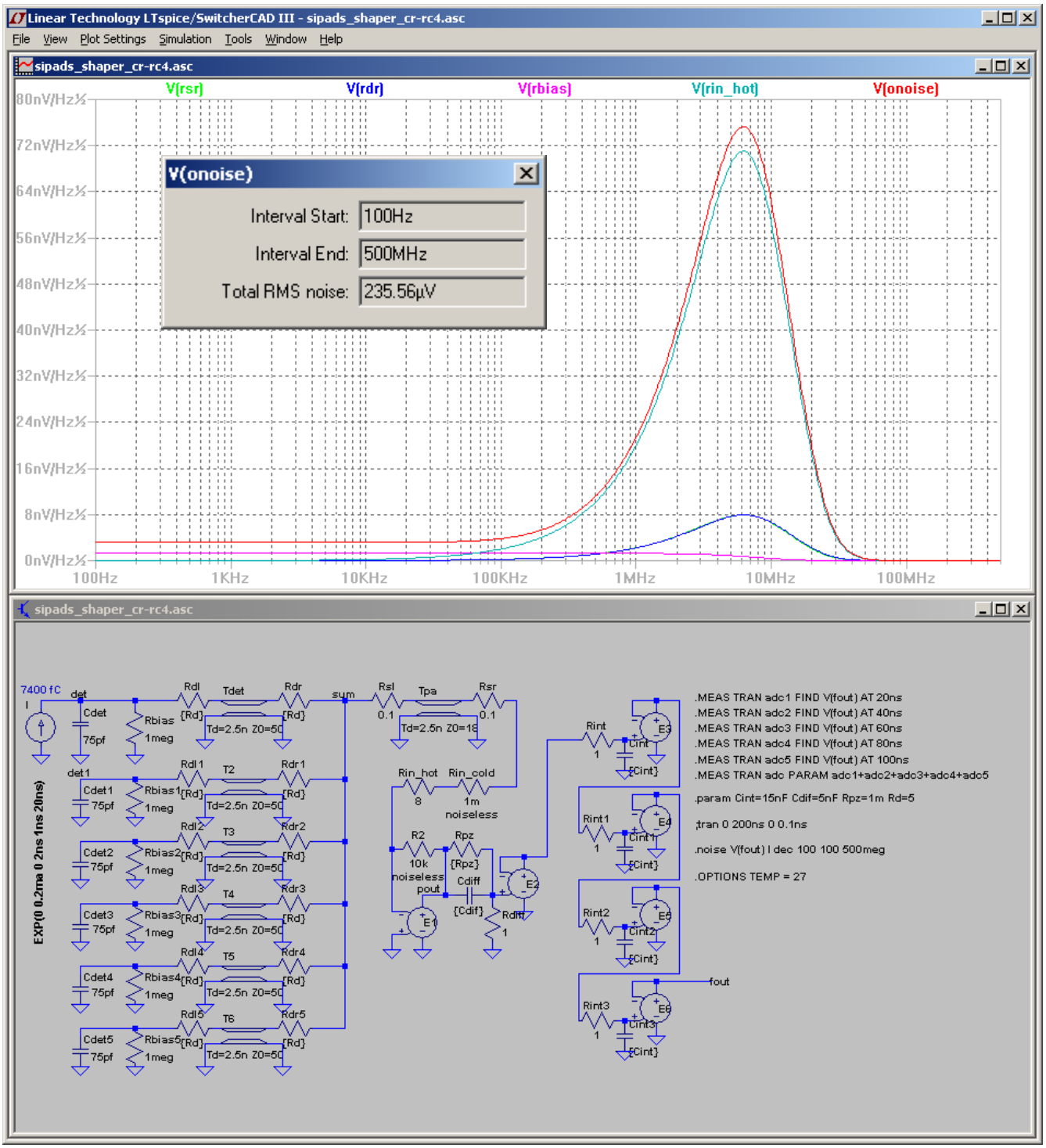
Linear Technology LTspice/SwitcherCAD III - sipads_shaper_cr-rc4.asc
File View Plot Settings Simulation Tools Window Help
sipads_shaper_cr-rc4.asc
V(rsr)
V(rdr)
V(rbias)
V(rin_hot)
V(onoise)
80nV/Hz½
72nV/Hz½
64nV/Hz½
56nV/Hz½
48nV/Hz½
40nV/Hz½
32nV/Hz½
24nV/Hz½
16nV/Hz½
8nV/Hz½
0nV/Hz½
100Hz
1KHz
10KHz
100KHz
1MHz
10MHz
100MHz
V(onoise)
Interval Start: 100Hz
Interval End: 500MHz
Total RMS noise: 235.56µV
sipads_shaper_cr-rc4.asc
7400 fC
EXP(0 0.2ma 0 2ns 1ns 20ns)
.MEAS TRAN adc1 FIND V(fout) AT 20ns
.MEAS TRAN adc2 FIND V(fout) AT 40ns
.MEAS TRAN adc3 FIND V(fout) AT 60ns
.MEAS TRAN adc4 FIND V(fout) AT 80ns
.MEAS TRAN adc5 FIND V(fout) AT 100ns
.MEAS TRAN adc PARAM adc1+adc2+adc3+adc4+adc5
.param Cint=15nF Cdif=5nF Rpz=1m Rd=5
.tran 0 200ns 0 0.1ns
.noise V(fout) I dec 100 100 500meg
.OPTIONS TEMP = 27
fout

Fig 9B.