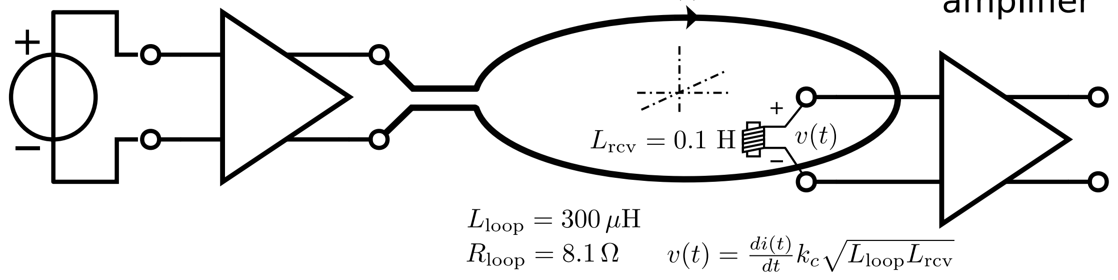
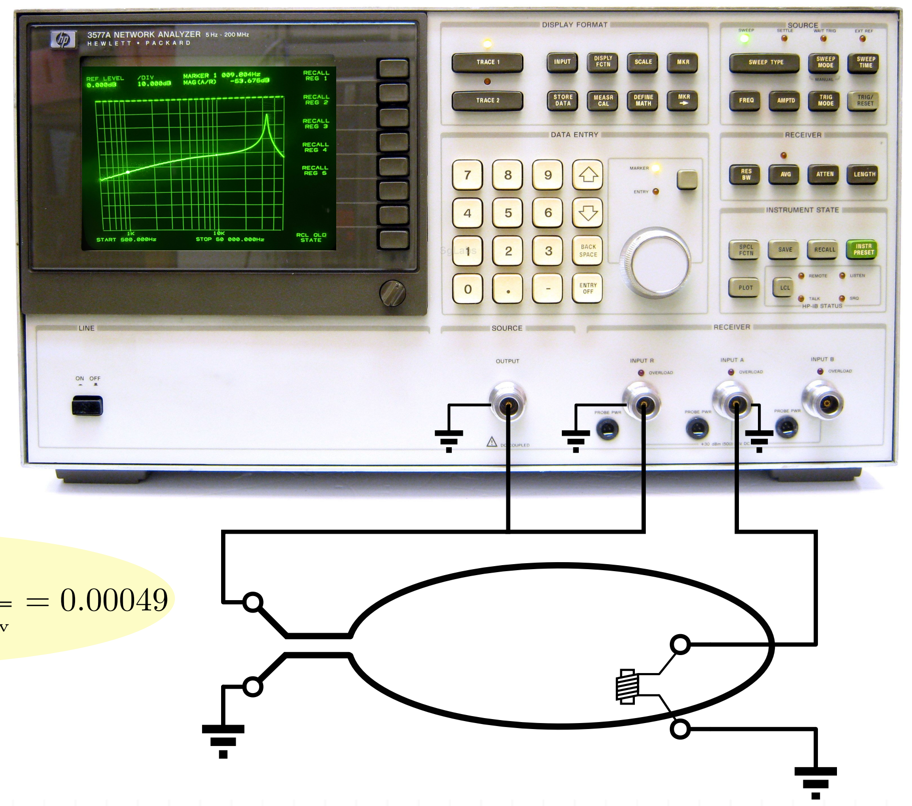
Application description



$L_{loop} = 300\,\mu$H
$R_{loop} = 8.1\,\Omega$ $\quad v(t) = \frac{di(t)}{dt} k_c \sqrt{L_{loop} L_{rcv}}$

Coupling factor measurement setup



$$k_c \approx 10^{\frac{dB\frac{V_A}{V_R}}{20}} \frac{R_{loop}}{2\pi f_m \sqrt{L_{loop} L_{rcv}}} = 0.00049$$

Specifications

functional specification

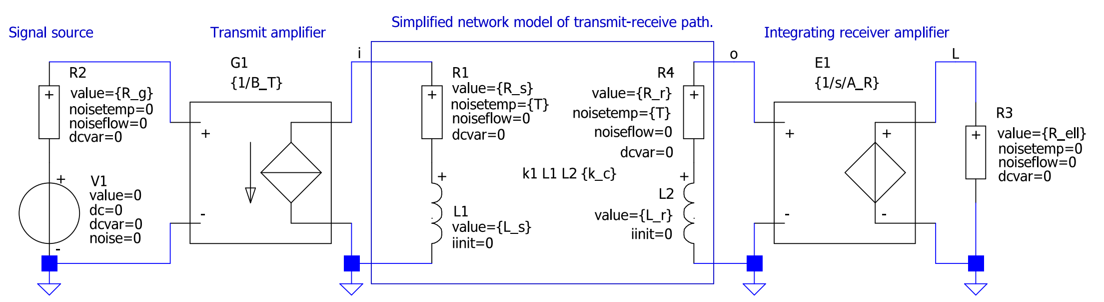
Table functional specification

symbol	description	min	typ	max	units
R_ℓ	Receiver load resistance	2000.0			Ω
V_i	Transmitter peak input voltage			1	V
V_o	Receiver peak output voltage at maximum input voltage	0.25			V
Z_i	Transmitter input impedance	$1.0 \cdot 10^4$			Ω
f_{fpl}	Maximum frequency for full-power	5000.0			Hz
f_{max}	Small-signal -3dB low-pass cut-off frequency	$1.5 \cdot 10^4$			Hz
f_{min}	Small-signal -3dB high-pass cut-off frequency			60	Hz
v_{on}	Zero-signal RMS output noise over -3dB frequency range			0.0001	V

power supply specification

Table power supply specification

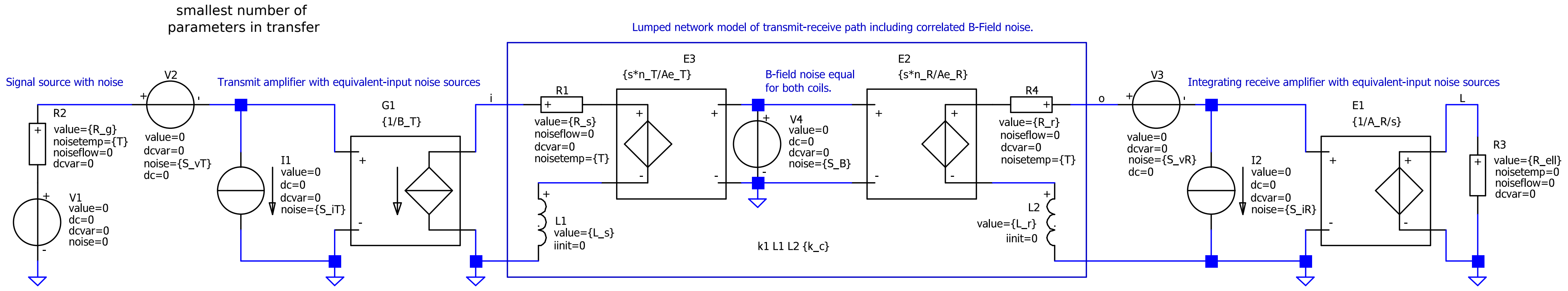
symbol	description	min	typ	max	units
V_N	Negative supply voltage	−15			V
V_P	Positive supply voltage			15	V



T1 matrix antenna

$$\begin{bmatrix} V_i \\ I_i \end{bmatrix} = \begin{bmatrix} \frac{L_s s + R_s}{\sqrt{L_r}\sqrt{L_s} k_c s} & \frac{-L_r L_s k_c^2 s^2 + L_r L_s s^2 + L_r R_s s + L_s R_r s + R_r R_s}{\sqrt{L_r}\sqrt{L_s} k_c s} \\ \frac{1}{\sqrt{L_r}\sqrt{L_s} k_c s} & \frac{L_r s + R_r}{\sqrt{L_r}\sqrt{L_s} k_c s} \end{bmatrix} \cdot \begin{bmatrix} V_o \\ I_o \end{bmatrix}$$

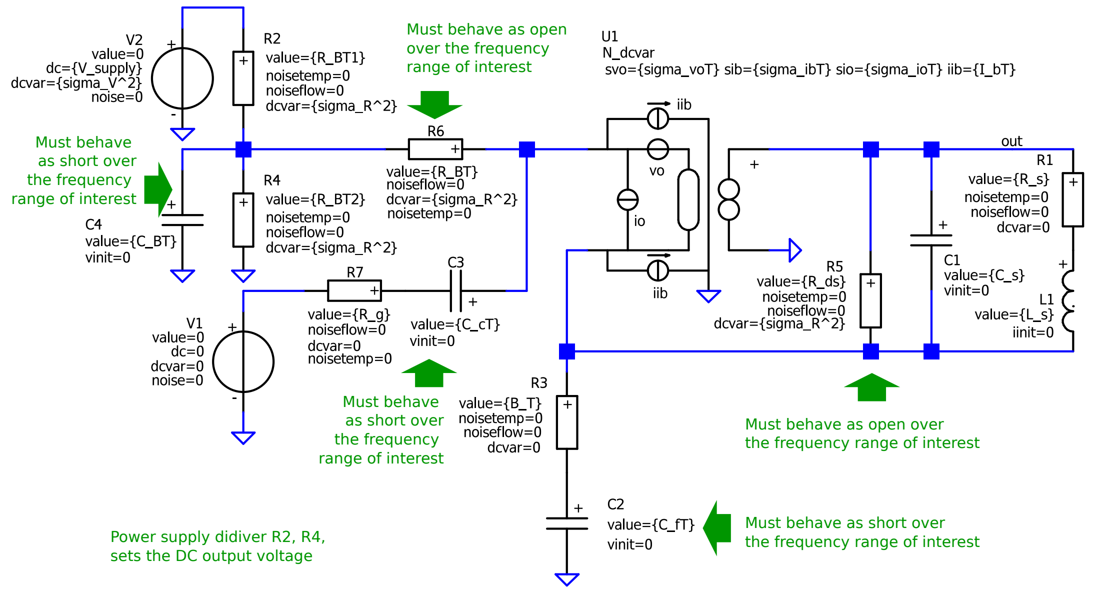
smallest number of parameters in transfer



Design of amplifier configurations

Feedback and biasing concept Transmitter

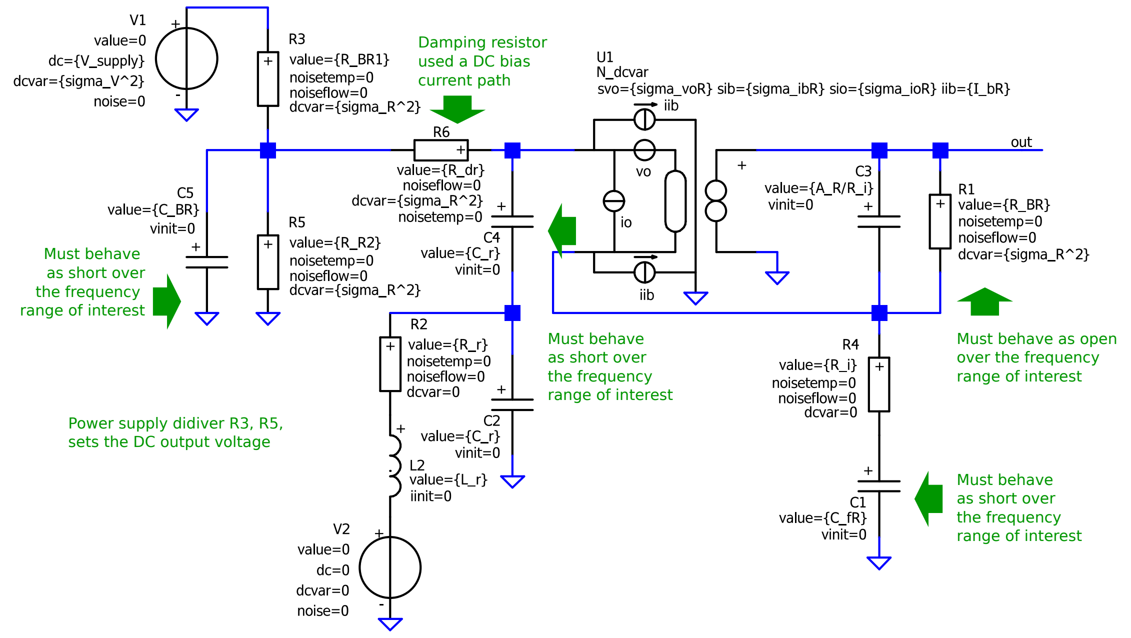
Including resistor for damping resonances.



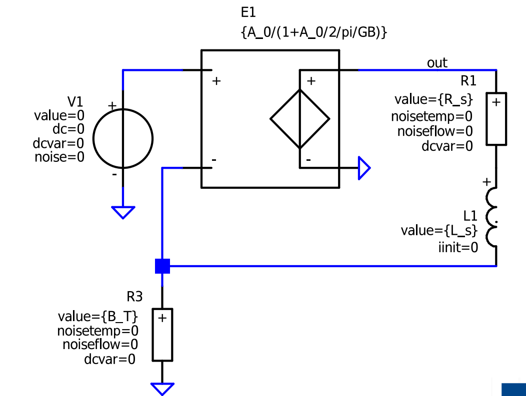
Find show-stopper values for biasing components, tolerances, and controller bias and offset

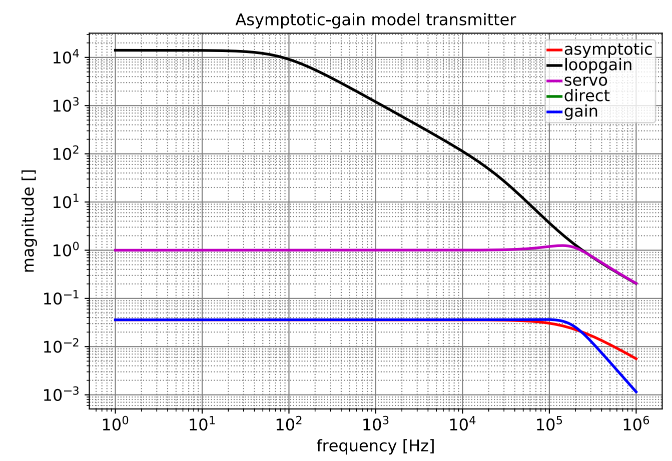
Feedback and biasing concept receiver

Including resistor for damping resonances.



Show-stopper value GB product Transmitter OpAmp

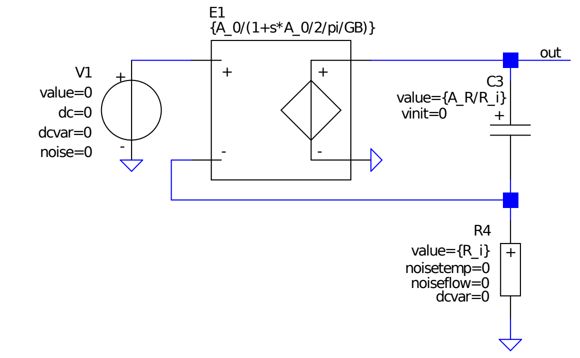




Find show-stopper value for GB product from Loop Gain-Poles product

$$GB_{min} = \frac{2\pi L_s f_{max}^2}{B_T}\ \text{Hz}$$

Show-stopper value GB product and DC gain Receiver OpAmp



Find show-stopper value for GB product from Loop Gain-Poles product

$$\frac{1}{2\pi A_R} >> f_{max}$$

high integrator gain: low loop gain

$$GB_{min} = \frac{1}{2\pi A_R}\ \text{Hz}$$

Find show-stopper value for DC gain from high-pass corner frequency of Servo fun

$$A_{0_{min}} = \frac{1}{2\pi A_R f_{min}}$$

Transmitter: TLV4111

TLV4110, TLV4111, TLV4112, TLV4113
FAMILY OF HIGH OUTPUT DRIVE OPERATIONAL AMPLIFIERS WITH SHUTDOWN
SLOS289E – DECEMBER 1999 – REVISED SEPTEMBER 2006

- High Output Drive . . . >300 mA
- Rail-To-Rail Output
- Unity-Gain Bandwidth . . . 2.7 MHz
- Slew Rate . . . 1.5 V/µs
- Supply Current . . . 700 µA/Per Channel
- Supply Voltage Range . . . 2.5 V to 6 V
- Specified Temperature Range:
  - T_A = 0°C to 70°C . . . Commercial Grade
  - T_A = −40°C to 125°C . . . Industrial Grade
- Universal OpAmp EVM

Updated specifications

design specification

Table design specification

symbol	description	min	typ	max	units
A_{0R}	Minimum DC gain of receiver OpAmp.	6555.0			
A_R	Minimum value of the receiver transmission coefficient A	$4.046 \cdot 10^{-7}$			s
A_{Rmin}	Minimum value receiver transmission coefficient A (integrating receiver)	$4.046 \cdot 10^{-7}$			s
B_T	Maximum value of the transmitter transmission coefficient B		27.07		Ω
GB_R	Minimum GB product of receiver OpAmp.	$9.425 \cdot 10^4$			Hz
GB_T	Minimum GB product of transmitter OpAmp.	$1.64 \cdot 10^4$			Hz
I_L	Receiver current drive capability	0.000125			A
Io_p	Minimum peak drive current of the transmit coil	0.03694			A
R_{dr}	Receiver damping resistance		$4.443 \cdot 10^4$		Ω
R_{ds}	Transmitter damping resistance		1200.0		Ω
R_{gmax}	Show-stopper value for noise contribution of I_noise_R2.		$6.464 \cdot 10^8$		Ω
R_{imax}	Show-stopper value for noise contribution of I_noise_R1.		235.0		Ω
SR_{vR}	Receiver voltage slew rate		7854.0		$\frac{V}{s}$
SR_{vT}	Transmitter voltage slew rate	$3.332 \cdot 10^4$			$\frac{V}{s}$
S_{iRmax}	Show-stopper value for noise contribution of I1_XU1.		$\frac{9.703 \cdot 10^{-24}}{2.492 \cdot 10^{-6} R_i^2 + 0.001197 R_i + 1}$		$\frac{A^2}{Hz}$
S_{iTmax}	Show-stopper value for noise contribution of I1.		$\frac{1.071 \cdot 10^{-11}}{R_g^2}$		$\frac{A^2}{Hz}$
S_{vRmax}	Show-stopper value for noise contribution of V1_XU1.		$3.893 \cdot 10^{-18}$		$\frac{V^2}{Hz}$
S_{vTmax}	Show-stopper value for noise contribution of V2.		$1.071 \cdot 10^{-11}$		$\frac{V^2}{Hz}$
V_{TRcoil}	Transmitter peak voltage drive capability	0.3536			V
V_{TRp}	Peak transmitter voltage	1.061			V
V_{rec}	Peak receiver input voltage	0.004494			V

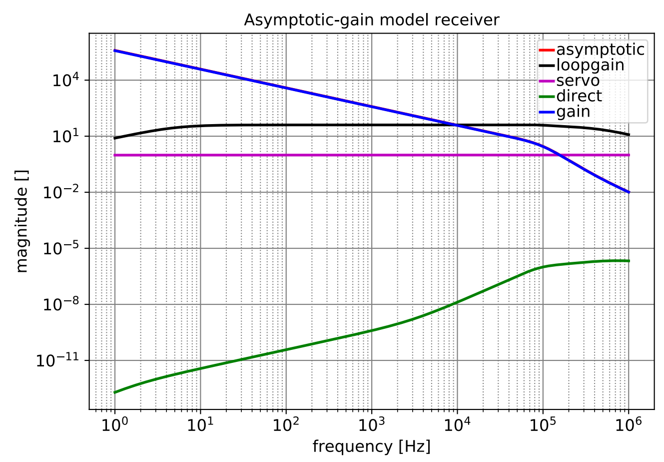
Receiver: OPA209

OPA209, OPA2209, OPA4209
SBOS426D – NOVEMBER 2008 – REVISED OCTOBER 2016

OPAx209 2.2-nV/√Hz, Low-Power, 36-V Operational Amplifier

1 Features

- Low Voltage Noise: 2.2 nV/√Hz at 1 kHz
- 0.1-Hz to 10-Hz Noise: 130 nV_{PP}
- Low Quiescent Current: 2.5 mA/Ch (Maximum)
- Low Offset Voltage: 150 µV (Maximum)
- Gain Bandwidth Product: 18 MHz
- Slew Rate: 6.4 V/µs
- Wide Supply Range: ±2.25 V to ±18 V, 4.5 V to 36 V
- Rail-to-Rail Output
- Short-Circuit Current: ±65 mA
- Available in 5-Pin SOT-23, 8-Pin MSOP, 8-Pin SOIC, and 14-Pin TSSOP Packages



Transmission matrix hearing loop system

$$\begin{bmatrix} V_i \\ I_i \end{bmatrix} = \begin{bmatrix} \frac{B_T A_R}{k_c \sqrt{L_s L_t}} & 0 \\ 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} V_o \\ I_o \end{bmatrix}$$

Frequency-independent transmitter
integrating receiver

Noise propagation and gain distribution

The minimum output noise is obtained with all designable contributions set to zero.
It is determined by the receive coil noise and the receiver gain.

$$v_{no} = \frac{40.5 \cdot 10^{-12}}{A_R}$$

With $v_{no_{max}} = 100\,\mu\text{V}$ we obtain $A_{R_{min}} = 405$ ns

Build and test

Select the transmitter's drive current level
1. In compliance with the OpAmp's drive capability
2. Large enough to establish the desired signal-to-noise ratio

Add to all components in the schematic of the final design
1. Keywords that indicate their main function
2. If possible: design equation and value
3. Else: selected value with motivation