Si581 Wideband Buffer Applications

The Si581 is a monolithic, closed loop, unity gain buffer amplifier. It features truly wideband, low distortion signal handling capability, and is an excellent complement to the Siliconix family of D/CMOS wideband/video switches and multiplexers (DG53x and DG54x).

Siliconix' wideband switches and multiplexers require high-performance impedance transformation to and from a 50- or 75-Ω environment without significant transmission loss. To drive coaxial cables or any "reactive" load, the Si581 may be used alone or in combination with a suitable wideband op amp. Reactive loads require a low-impedance source (<50 Ω) to preserve the operating bandwidth. Features and characteristics of the Si581 are listed in Table 1.

Table 1. Si581 Typical Characteristics (R_L = 100 Ω)

Parameter	Condition	Si581
dc output current	R_L = 100 Ω	± 70 mA
Slew rate	± 5-V supplies	800 V/µs
−3-dB bandwidth (MSBW)	V_O = 1 V_{p-p}	450 MHz
−3-dB bandwidth (LSBW)	V_O = 5 V_{p-p}	90 MHz
Voltage gain	V_O = 5 V_{p-p}	0.97 V
Input offset voltage	V_O = 5 V_{p-p}	2 mV
Input bias current	V_O = 5 V_{p-p}	± 20 µA
dc output resistance	V_O = 5 V_{p-p}	2 Ω
Power supply rejection	V_O = 5 V_{p-p}	50 dB

Circuit Description

The Si581 is fabricated with a very high-performance complementary bipolar process which provides high-frequency NPN and PNP transistors with gigahertz transition frequencies (f_T). Power supplies are rated at ± 7-V maximum with the data sheet parameters specified at supplies of ± 5 V. Figure 1 displays the circuit symbol, and Figure 2 reveals the simplified internal circuit diagram.The input stage is a complementary pair of differential transistors connected in parallel to provide excellent symmetry, overload recovery, and low noise. At the input, the NPN and PNP transistors have slight mismatches that give rise to the net bias current specification. Depending on the direction of the mismatches, the bias current may flow into or out of the input terminal.

The symmetrical class AB output stage provides current sourcing or sinking and relatively constant output impedance during load excursions. The gain and level shift stages provide power supply rejection at low frequencies; they also contribute to the excellent reverse gain and phase characteristics of the buffer.

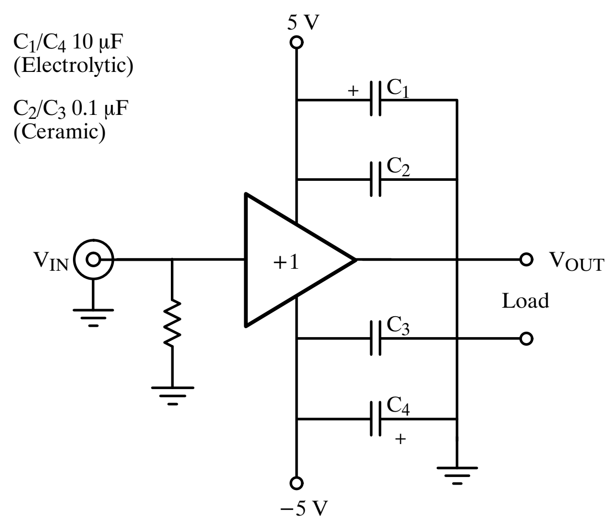


Figure 1. Circuit Symbol of the Si581

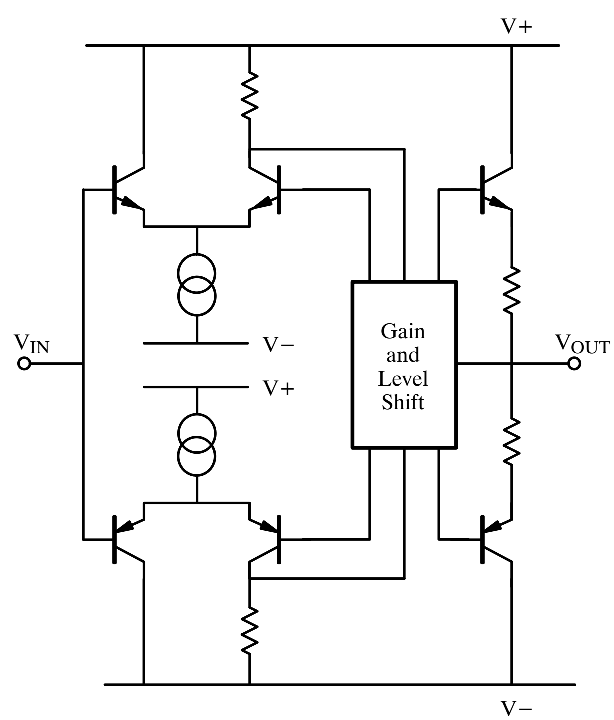
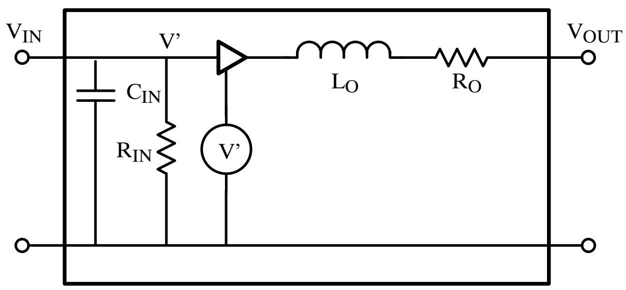


Figure 2. Simplified Internal Circuit Diagram of the Si581

Small-Signal Equivalent Circuit

Equivalent input and output networks to model the small-signal characteristics of the buffer can be obtained from the Si581 data sheet. The model in Figure 3 surrounds an ideal unity-gain buffer with reactive components whose values are obtained from the input and output impedance curves. When the source impedance is known, then a network simulating the effects of the reverse-gain characteristic may be added from input to output.



$$|Z_{IN}| = \frac{R_{IN}}{\sqrt{1 + \omega^2 C^2_{IN} R^2_{IN}}}$$

$$< Z_{IN} = TAN^{-1} \omega C_{IN} R_{IN}$$

$$|Z_O| = \sqrt{R_0^2 + \omega L_0^2}$$

$$\angle Z_O = TAN^{-1} \frac{\omega L_O}{R_O}$$

At 1 MHz: $Z_{in} = 100\ k\Omega \angle -40°$
$R_{in} = 130.5\ k\Omega$
$C_{in} = 1.02\ pF$
At 100 MHz: $R_O = 1.9\ \Omega$
$L_O = 8.4\ nH$

Figure 3. Small-Signal Equivalent Circuit

Power Supply Decoupling

Figure 1 displays a four-terminal device with input, output, and positive/negative supplies. The ground reference point is located in both of the positive/negative power rails. This location explains the necessity for good power supply decoupling, especially in high-frequency applications. In pulse applications, good power supply decoupling is also important because the output stage cannot dump energy into a load if the power rails are inductive.

The recommended power supply decoupling consists of a 10-μF electrolytic capacitor in parallel with a 10-nF to 100-nF miniature ceramic. Both the electrolytic and the miniature are connected as close as possible to the buffer supply pins. The ground return for the load is the common connection of the decoupling capacitors. Ground plane construction is recommended because it provides a low inductance return for the load.

Forward and Reverse Gain

An ideal buffer has exact unity gain from input to output, irrespective of load. This characteristic is called "forward gain." An ideal buffer also allows a variety of complex (RLC) loads to be driven without modifying the existing input conditions. This characteristic is called "reverse gain." Reverse gain should be zero. Because of the wideband nature of the Si581, forward and reverse gain are specified in S-parameters. S-parameters are reflection and transmission coefficients that are used to describe a linear two-port network in the same way as Y, Z, or *h* parameters. Short or open circuits are misnomers in RF circuits. Instead, the network is defined in terms of incident and reflected waveforms. Waveforms are easier to measure and the results are more realistic above 50 to 100 MHz.

At 500-mV signal levels, the Si581 forward gain, S_{21}, is −0.2 dB, + 1° at 100 MHz. At the same frequency and amplitude, the reverse gain is −60 dB, +145°. An industry-standard conventional wideband buffer specifies forward gain at approximately −0.5 dB, 0° while reverse gain is specified at only −25 dB, −30° at 100 MHz. This shows that the unique design of the Si581 significantly improves reverse gain.

Applications

Figure 4 shows a wideband crosspoint system for a broadcast video studio switcher or a financial data distribution system. The 8 × 4 wideband crosspoint is formed by four DG538A 8-channel multiplexers with their inputs connected in parallel. Each input bus created by the crosspoint represents a considerably reactive load to the input signals. This reactive load would cause unacceptable signal degradation if it were connected directly to the 75-Ω input sources.

The input buffers provide a stable input termination, a low output impedance to drive the input bus, and a high output-to-input isolation. These features enable the input conditions to remain independent of the multiplexer loading.

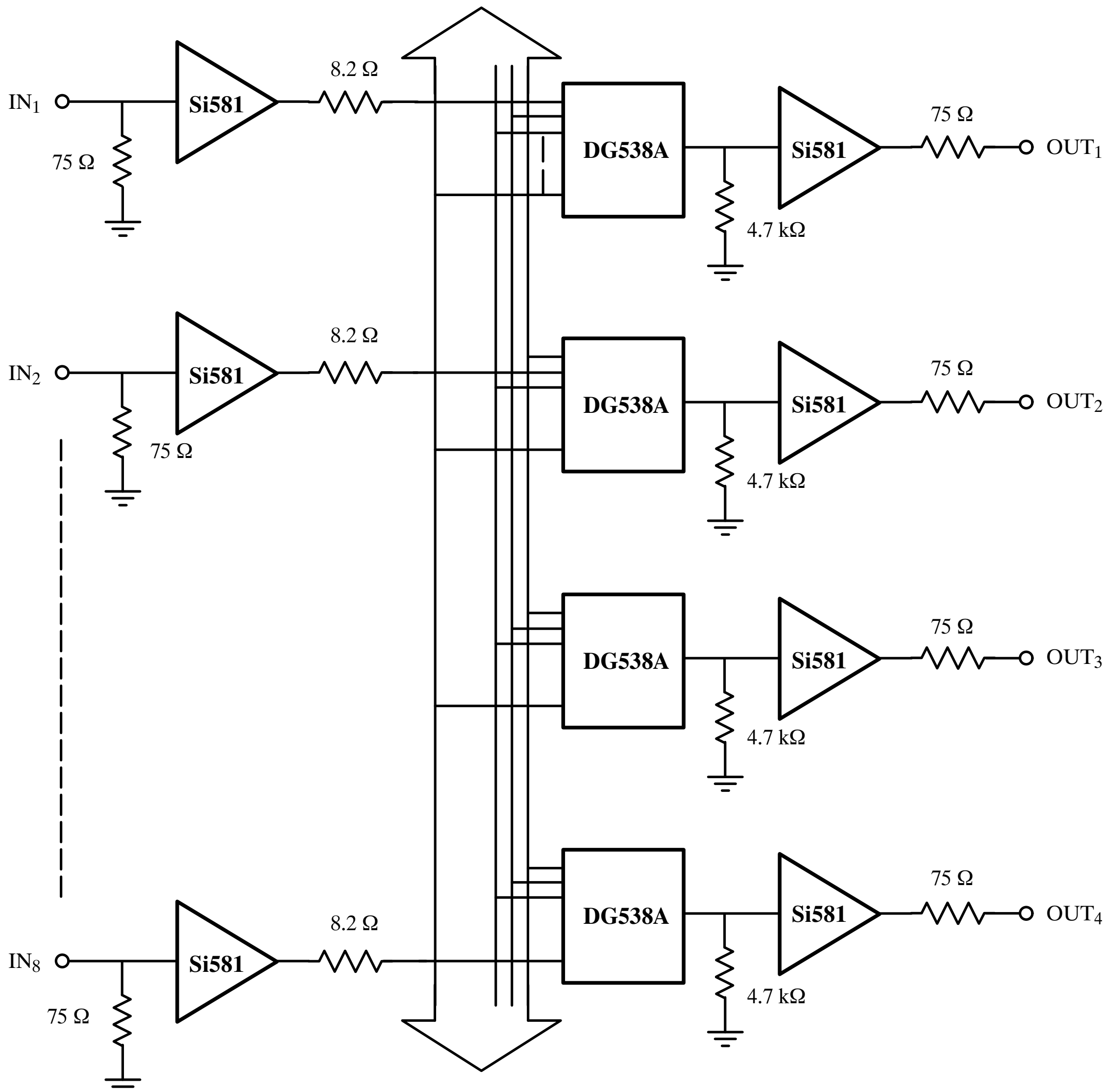
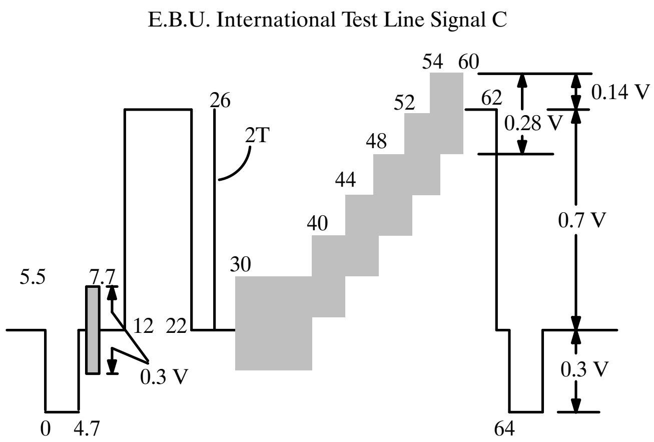


Figure 4. Wideband 8 × 4 Crosspoint Using DG538A Multiplexers and Si581 Buffers

The output buffers provide a "high" input impedance to the multiplexer outputs. This reduces the inevitable transmission loss if the load resistor is 75 Ω. The low output impedance of the buffers allows a single-series resistor in each output to provide reverse termination of 75 Ω. When correctly terminated, this resistor causes a nominal −6 dB loss at the output, but it also isolates any load capacitance from the buffer output terminal. This is important because load capacitance causes amplitude peaking in the passband. The series 8.2-Ω resistor at the input buffers also isolates the switch reactance from the buffer output. Measured performance of this system is shown in Table 2.

Table 2. Wideband 8 × 4 Crosspoint Using DG538A Multiplexers and Si581 Buffers

−3 dB Bandwidth	145 MHz
−0.3 dB Bandwidth	50 MHz
Phase Shift to 100 MHz	0 to −97°, Linear Slope
Differential Gain	−0.03% EBU Test Signal
Differential Phase	−0.03° EBU Test Signal



a. Standard Test Waveform

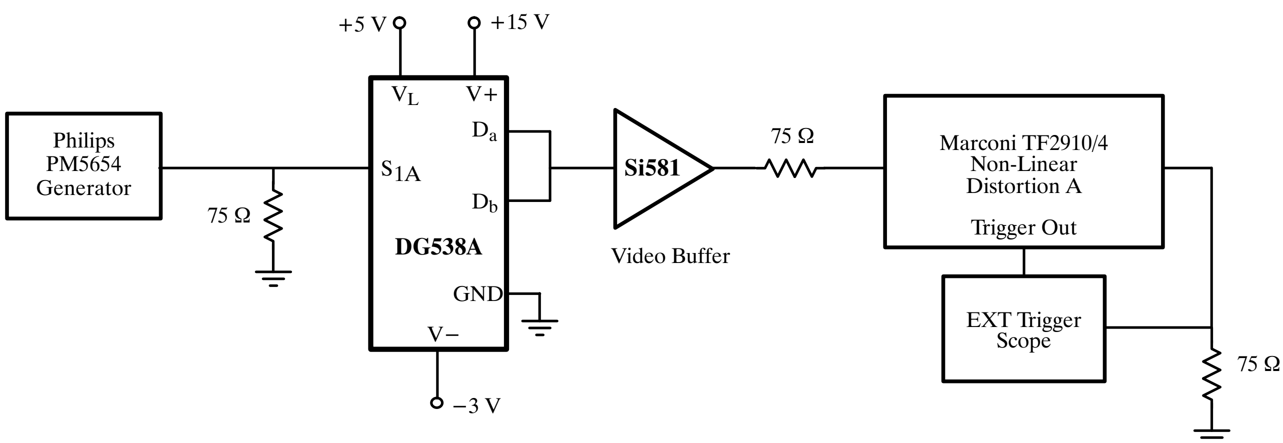
Definitions

Differential Phase: Measured in degrees, this is the phase shift of the color subcarrier resulting from a change in the amplitude of the associated luminance components. Differential phase shows up in NTSC pictures as a change in hue, a color change more noticeable in a shaded area of the picture.

Frequency related phase shifts (as opposed to differential phase) will cause no change in picture quality since both color burst and chrominance are equally shifted.

Differential Gain: Expressed as a percentage, this is a form of distortion resulting from changes in the amplitude of the chrominance signal as a function of luminance amplitude.

The effect on NTSC and PAL pictures is a change in color saturation with changing luminance level. The eye is fairly tolerant to differential gain since the resulting picture changes are fairly subtle. For instance, a brightly colored car travelling from a sunny area of the picture to a shaded area would appear as though its body color intensity had suddenly changed.



b. Differential Phase and Gain Test Configuration

Figure 5. Video Waveforms and Specification Definition

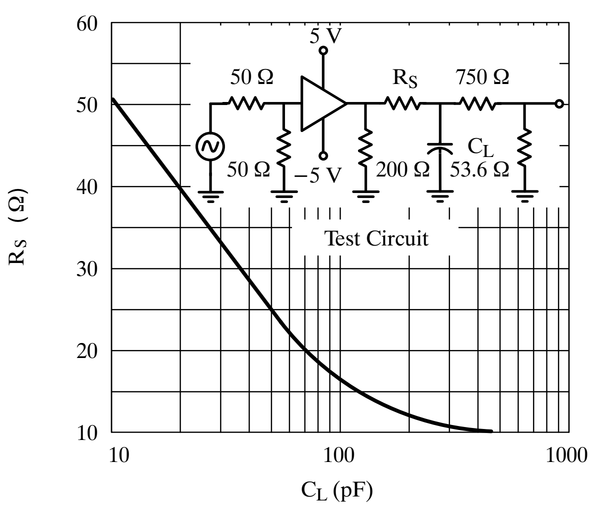


Figure 6. Series Isolating Resistor and C_{LOAD} Selection

To prevent the 6-dB loss at the output, a wideband amplifier, such as the Si582, configured for a gain of 2 may be used.

Performance depends significantly upon high-frequency ground plane techniques, symmetrical layout, and the correct use of the series isolating resistor. Where different capacitive loads are encountered (i.e., an 8 × 2 crosspoint employing just two DG538A multiplexers), the curve in Figure 6 will assist in selecting the correct isolating resistor. As with all high-frequency work, resistors should be noninductive.

In a design similar to Figure 4, the Si581 may be used with the DG54X family of wideband switches to perform IF and or bandwidth switching in numerous receiver applications such as HF communications equipment and multistandard TV chassis.

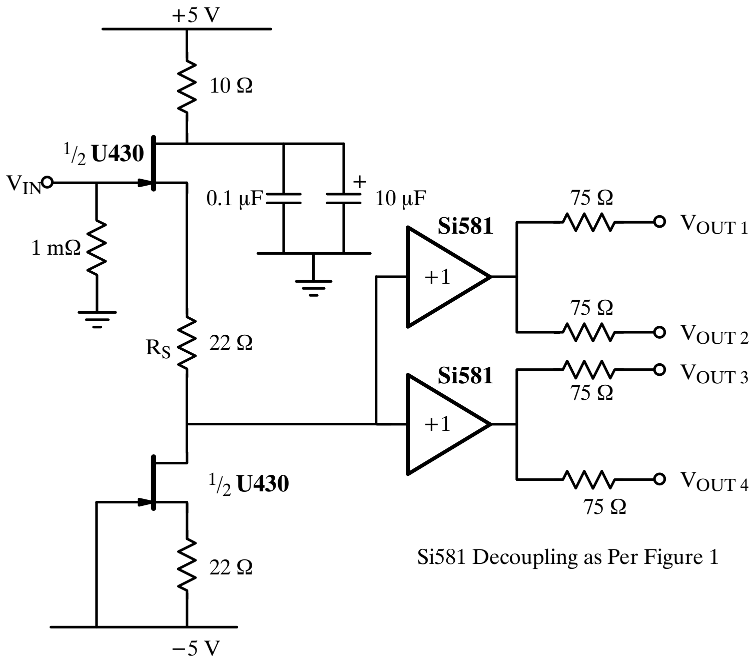


Figure 7. Multiple-Output High-Performance Buffer

Feeding several cables from one high-impedance wideband signal source can be done with the circuit shown in Figure 7. For optimum broadcast video performance (< 0.1% differential gain, < 0.05° differential phase, EBU), the Si581 should be restricted to driving two reverse-terminated 75-Ω loads. This would give a nominal 75-Ω total output loading. For more outputs, several buffers may be driven from a simple JFET dual-source follower as shown in Figure 7.

The input stage is a compound source follower. It uses a matched pair of JFETs and equal value source resistors to reduce the input-to-output offset from several volts without correction to approximately 40 mV. The output impedance of the input stage is $1/g_{fs} + R_s$; this impedance drives the inputs of the paralleled Si581 buffers. The total input to output offset includes the Si581 buffers. For low-impedance signal sources (50 Ω, 75 Ω), the JFET stage is not necessary. The circuit in Figure 8 is useful when precision offsets are required.

To vary both the current in Q_1 and the voltage across the 33-Ω resistor, Q_2 is added to the input source follower. Q_2 is controlled by the chopper stabilized op amp, the 7652, which is configured as an inverting integrator. The 7652 drives Q_2; this varies the current in Q_1 and drives the input-to-output offset to zero. Multiple Si581 buffers can be included in this scheme, but the offset will be the net average of all the offsets as they are summed by the 7652 input. Variations of the above method, with or without offset correction, make excellent wideband antenna amplifiers. This is due to the square law JFET transfer characteristic and the >30-dBm third-order intercept performance of the Si581.

Single-Supply Operation

The buffer may be powered from a single 10-V supply without special precautions. A typical application is shown in Figure 9. The input is biased to mid-operating point (5 V here) and is ac coupled. The value of R_1 and R_2 is chosen with the limits of the input bias current in mind. Thus, 27 kΩ is a suitable value that leads to an input impedance of 13.5 kΩ (R_1 in parallel with R_2) at low frequencies. Note that for dc loads referenced to ground, the quiescent current is increased by the input bias voltage/R_L. The test waveform used to obtain the results is shown in Figure 5.

Cable Shield Driver

To reduce the effective load capacitance seen by the cable driver, the Si581 may be used to drive the outer shield of an unterminated coaxial cable. This is useful in situations when the bandwidth requires very low effective load capacitance and reverse termination cannot be employed because of the transmission loss. Figure 10 shows a typical arrangement where one buffer is the main cable driver and another buffer drives the cable outer shield. In this situation, the cable capacitance seen by IC_1 is bootstrapped by IC_2. This permits high-speed data transmission by IC_1.

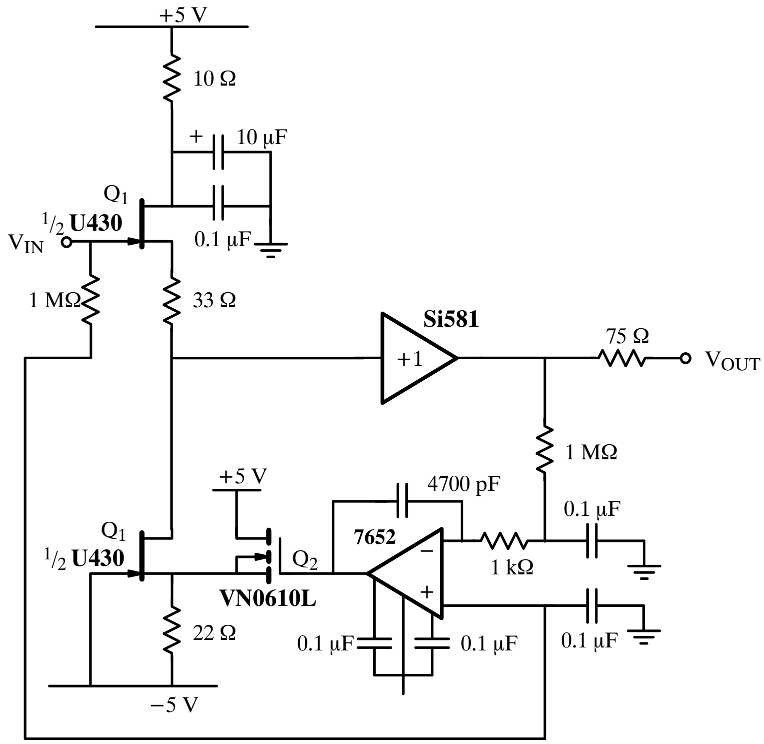


Figure 8. Precision High-Performance Buffer

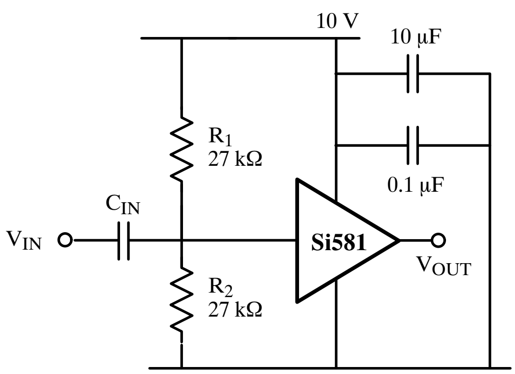


Figure 9. Single-Supply Operation

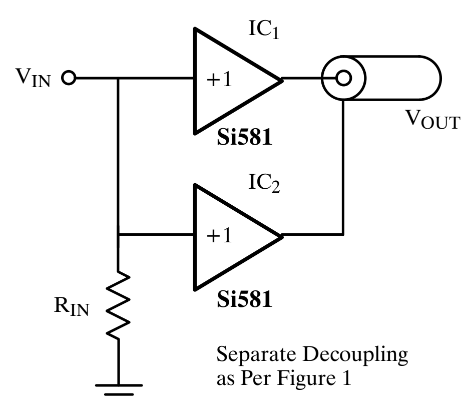


Figure 10. Cable Shield Driver

References

Powell, Gareth, "Microprocessor-Compatible Multiplexers Facilitate Video Switching Designs," Siliconix Applications Note AN502.

Carson, Ralph S, "High-Frequency Amplifiers," John Wiley and Sons, 1982.