Composite Instrumentation Amp Extends CMRR Frequency Range 10×

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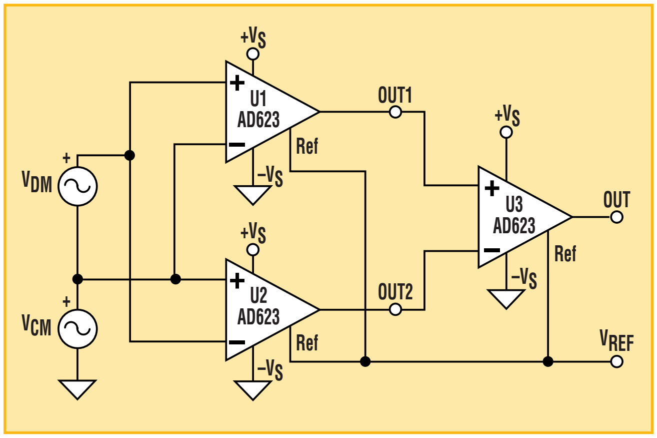
CIRCLE 520

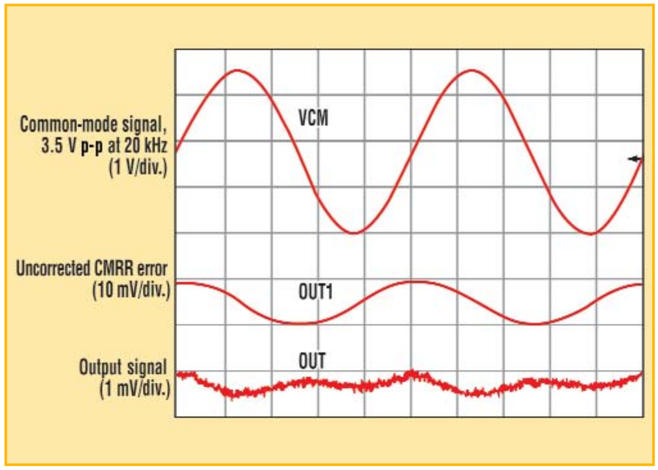
Instrumentation amplifiers are the building blocks commonly used in industrial, medical, and military systems. The primary benefit of such a component is its ability to reject common-mode signals while amplifying a differential-input signal.

While all instrumentation amplifiers perform well at low frequencies, their ability to reject common-mode signals usually degrades rapidly as the frequency increases.

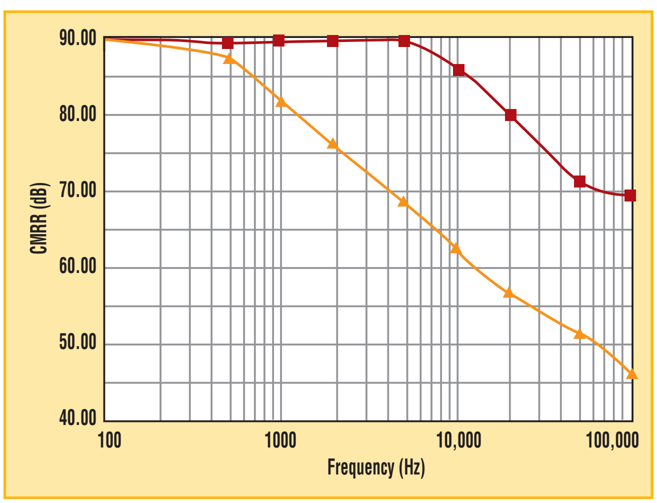
The circuit in Figure 1 is a composite instrumentation amplifier with a high common-mode rejection ratio (CMRR). It features an extended frequency range over which the instrumentation amplifier has good common-mode rejection *(Fig. 2)*. The circuit consists of three instrumentation amplifiers. Two of these, U1 and U2, are correlated to one another and connected in antiphase. It is not necessary to match these devices because they are correlated by design. Their outputs, OUT1 and OUT2, drive a third instrumentation amplifier that rejects common-mode signals and



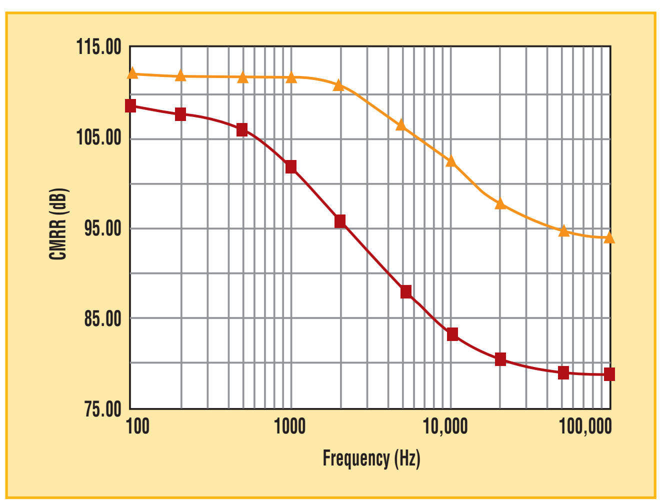
1. **This composite instrumentation amplifier has a high CMRR that does not degrade quickly over a wide frequency range.**



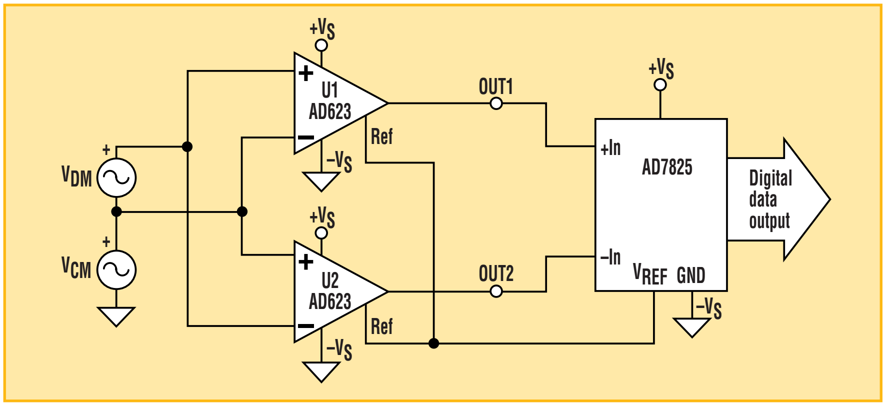
2. **A performance "snapshot" of the circuit in Fig. 1 at 20 kHz is shown.**



3. **A plot of the system CMRR versus frequency at a gain of 2 is shown.**



4. **The performance of the system at a gain of 100 is shown.**



5. The OUT1 and OUT2 signals of the first stage can directly drive an analog-to-digital converter (ADC), allowing the ADC to reject the common-mode signal.

amplifies differential signals. The overall gain of the system can be determined by adding external resistors. Without any external resistors, the system gain is 2 *(Fig. 3)*. The performance of the circuit with a gain of 100 is shown in Figure 4.

Since U1 and U2 are correlated, their common-mode errors are the same. Therefore, these errors appear as a common-mode input signal to U3, which rejects them. In fact, if it is necessary, OUT1 and OUT2 can directly drive an analog-to-digital converter (ADC). The differential-input stage of the ADC will reject the common-mode signal, as seen in Figure 5.

Negative Resistance Nulls Potentiometer's Wiper Resistance

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CIRCLE 521

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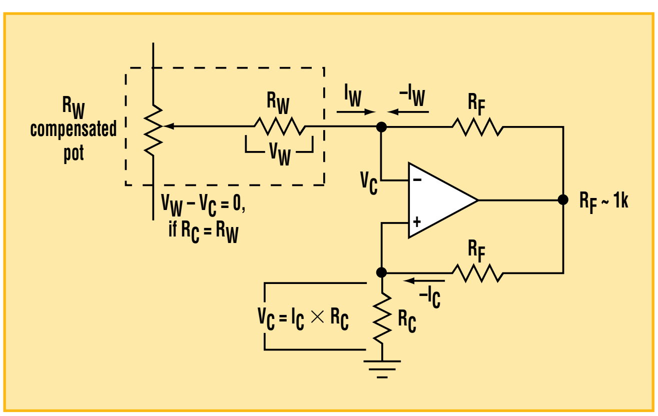
While almost always called "potentiometers" (which are technically defined as three-terminal variable voltage dividers), many "pots" actually end up being used as variable resistors (rheostats) instead. When used as a variable resistor, all pots—whether electromechanical or electronic—suffer from the parasitic error of "wiper resistance."

In electromechanical pots, wiper resistance arises because the point of contact between the wiper and the resistance element inevitably makes an undesirable nonzero contribution ("R_W" in the figure) to the total resistance. The effective resistance of the pot can therefore never be adjusted to zero, but instead has a minimum value of R_W. Any nonzero wiper current (I_W) therefore produces a parasitic nonzero wiper voltage: $V_W = I_W R_W$. A similar effect plagues electronic (i.e., digitally controlled) potentiometers (DCPs). DCPs escape the contact-resistance problems of the mechanical pot but must contend instead with the relatively large R_{ON} resistances (usually tens of ohms) of the FET switches in the multiplexed resistor array that substitute for the mechanical pot's wiper. For these DCPs, $V_W = I_W R_{ON}$.

An earlier IFD *("Active Cancellation of Potentiometer Wiper Resistance,"* ELECTRONIC DESIGN, *June 14, 1999, p. 104)* presented one idea for active cancellation of wiper resistance. Although effective when it can be used, the method suggested in "Active..." requires that one termination of the pot resistance element be available as a V_W sense point. It is therefore not available for use by the application circuit. This requirement makes the "Active..." approach incompatible with applications in which both ends of the resistance element are needed.

By contrast, the wiper-resistance cancellation method presented here doesn't suffer from this limitation *(see the figure)*. This leaves both terminals of the resistance element available for use in the application circuit. This idea assumes that R_W can be approximated by a separate cancellation resistor R_C. To the extent this assumption is correct and $R_C = R_W$, then $I_C = -I_W$ and the voltage developed at the noninverting op-amp input $= V_C = I_C R_C = -I_W R_W$.

If ideal operation of the op amp can be assumed (i.e., negligible offset and gain errors), then V_C will appear at both op-amp inputs, driving the right-hand end of R_W to V_C. This, in turn, will pull the left-hand end of R_W to $V_W - V_C = V_W - V_W = 0$, thus canceling the effects of R_W.



A cancellation resistor R_C is used to cancel wiper resistance while leaving both terminals of the digitally controlled potentiometer available for use in the application circuit.

Of course, there's no such thing as a "free lunch," and the R_W cancellation effect will be no better than the accuracy of the approximation $R_C = R_W$. In some cases, trickery can be employed to improve the guess for the value of R_C. For example, if the pot to be compensated is one element of a multisection DCP integrated circuit in which one of the elements can be dedicated for duty as an R_C ($R_W = R_{ON}$) reference, then the accuracy of the R_C/R_W compensation may be very good indeed. This effect is due to the inherently good tracking of elements in most monolithic chips. However, in other scenarios (e.g., mechanical pots and digital pots in which no internal R_C reference is available), the compensation may be less accurate and the cancellation will therefore be less than perfect. Nevertheless, a useful improvement in accuracy in the relationship of resistance-to-pot-setting may still be attainable.

High-Efficiency Inverter Drives Compact Fluorescent Lamps

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CIRCLE 522

The inverter circuit shown is designed to drive a 7-W, four-pin compact fluorescent lamp (CFL) from a 12-V dc power supply. The main features of this inverter circuit include direct-drive capability, preheat for improved startup, high efficiency, and a simple and economical configuration. While the inclusion of a preheating circuit helps to prevent end-blackening of the bulb, the direct-drive arrangement ensures trouble-free start-up in all conditions.

The circuit finds application in solar-powered lighting, internal automobile lighting, and emergency lighting systems. The inverter is a direct-drive push-pull oscillator. The SG3524 PWM integrated circuit (U1) drives the inverter. Capacitor C4 and resistor R3 are chosen to set the oscillator frequency at around 26 kHz. MOSFETs Q1 and Q2 (IRFZ44) are used as power devices, improving the efficiency of the inverter.

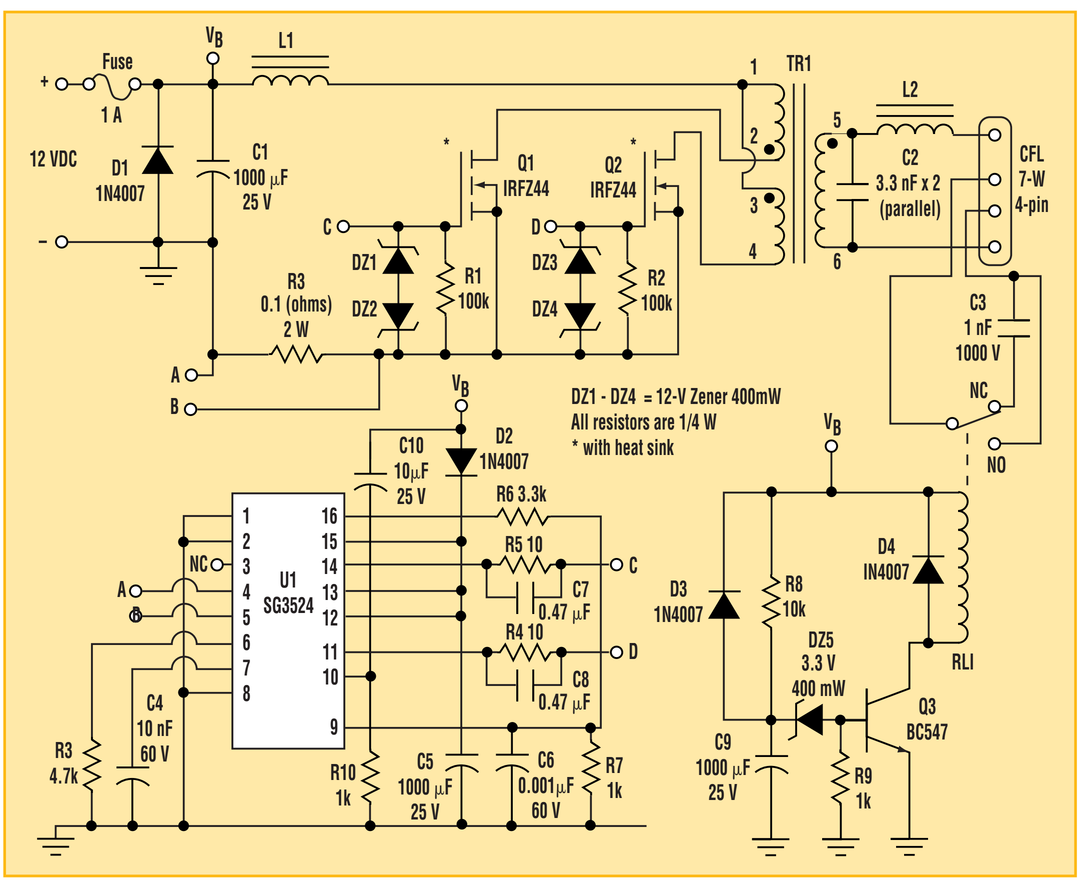
Transistor Q3 along with the resistor R8, relay RL1, capacitor C9, and zener diode DZ5 form the preheating circuit. Diode D1 and a fuse have been included in the circuit to provide reverse-polarity protection.

This circuit has been built and tested using a 12-V dc input. This configuration results in a light output of 370 lumens using a 7-W, four-pin CFL. The measured circuit efficiency is around 85% at a switching frequency of 26 kHz.

The winding details for the two inductors and the transformer are given in the table.

WINDING DETAILS

Transformer TR1 start pin	Core: EE 25/13/7 End pin	Wire gauge SWG	Turns	Inductance
2*	1	28	21	28 µH
3*	4	26	21	28 µH
5	6	38	450	17 mH
*Bifilar winding				
Inductor L1	Ferrite rod 25 mm (l) × 5 mm (dia.)	#26 SWG	100	
Inductor L2 start pin	Core: EE 25/13/7 **End pin**	**Wire gauge SWG**	**Turns**	**Inductance**
1	2	27	215	8.2 mH



This pulse-width modulation inverter circuit drives a 7-W, four-pin compact fluorescent lamp (CFL) from a 12-V dc power supply with an efficiency of 85%.