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Gain-of-two instrumentation amplifier uses no external resistors

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An instrumentation amplifier offers precise gain without feedback resistors, and, at any value of gain, it provides high input impedances at its noninverting and inverting inputs. In a typical IC instrumentation amplifier, a single resistor that connects across two gain-adjustment pins determines the circuit's overall gain. Integrated versions of most instrumentation amplifiers allow the pins to remain open for unity gain but require finite-value gain-setting resistors for gains exceeding one. Although the gain-adjustment resistor might comprise a tiny surface-mounted device, its electrodes and internal resistive layer extend the conductive surface connected to the IC's gain-adjustment pins. The extended surface acts as an antenna and thus makes the amplifier more susceptible to stray external electromagnetic fields.

Figure 1 shows an instrumentation amplifier that offers a gain of two without using any external resistors. The circuit comprises a cascade of a symmetrical, differential-output amplifier, formed by two channels of IC$_1$; an Analog Devices (www.analog.com) AD8222 instrumentation amplifier; and a difference amplifier comprising one half of IC$_2$, a second AD8222. All three instrumentation-amplifier sections in the circuit provide a standalone gain of one. Because the differential outputs of the first stage have opposite signs, their difference is twice

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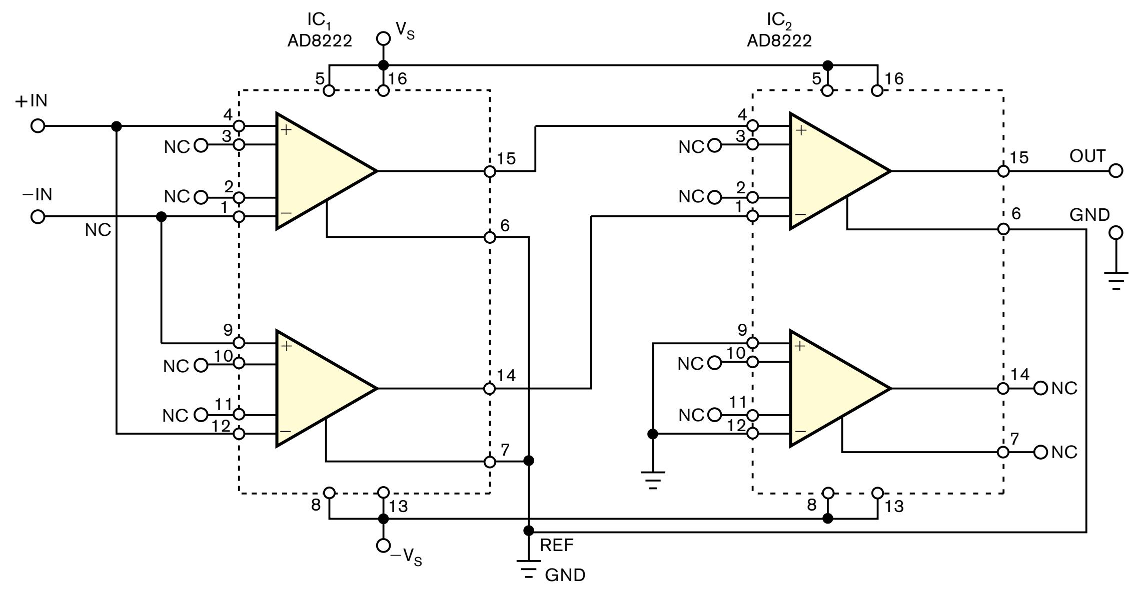

Figure 1 Based on two dual-section instrumentation amplifiers, this composite instrumentation amplifier offers a gain of two with an error margin of less than 0.06% and requires no gain-setting resistors.

that of the difference of the input signals.

The circuit's worst-case gain error does not exceed the value of $\delta_2=3\delta_1$, where, at a gain of one, δ_1 represents the maximum gain error of one section of the AD8222. For B-grade ICs, you calculate the value of δ_2 as $\delta_2\leq$ 0.06% (**Reference 1**). Typically, the value of δ_2 rarely reaches its maximum value. Given the reasonable assumptions that all three amplifiers' gain errors are independent and obey a gaussian distribution, the probability of occurrence of $\delta_2=3\delta_1$ is about 1⁄20 the probability of encountering a single amplifier that has a maximum gain error of δ_1.**EDN**

REFERENCE

1 "AD8222 Precision, Dual-Channel Instrumentation Amplifier," Analog Devices Inc, www.analog.com/en/prod/0,2877,AD8222,00.html.

Analog switch converts 555 timer into pulse-width modulator

Jordan Dimitrov, Tradeport Electronics, Vaughan, ON, Canada

This Design Idea describes a new approach to producing a variable-duty-cycle waveform from a 555-based free-running oscillator. The circuit's wide modulation range, highly linear control over a wide range of duty-cycle values, and excellent linearity make it ideal for PWM (pulse-width-modulation)-based control applications. **Figure 1** shows the basic circuit, which works as follows: When IC_1's output goes high, switch S_1 closes, and IC_1's internal discharge, switch S_2, opens. Capacitor C_1 charges through R_1 and R_2. When IC_1's output goes low, S_1 opens, and S_2 closes, discharging C_1 through R_2 and R_3.

The generic configuration works well for producing a fixed-value duty cycle.

(continued on pg 86)

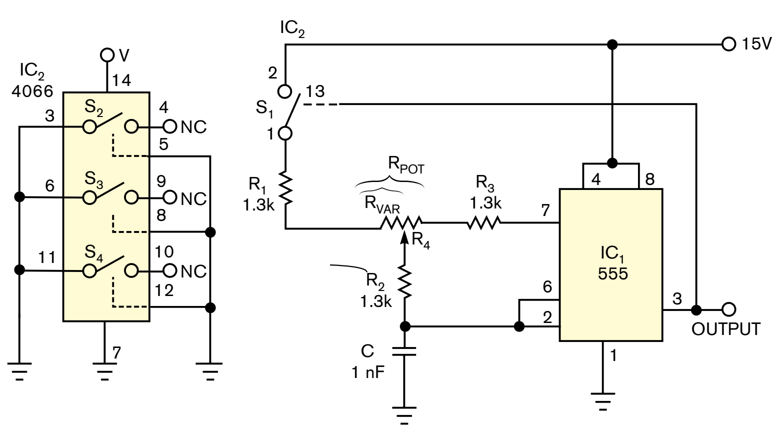

Figure 2 Add a potentiometer, R_4, to produce an output pulse that has a manually variable duty cycle.

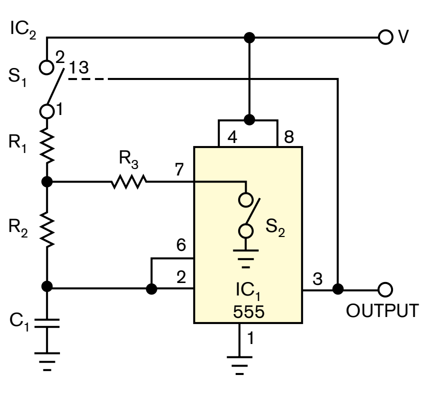

Figure 1 An external analog switch and a 555 timer provide a free-running oscillator with a fixed duty cycle.

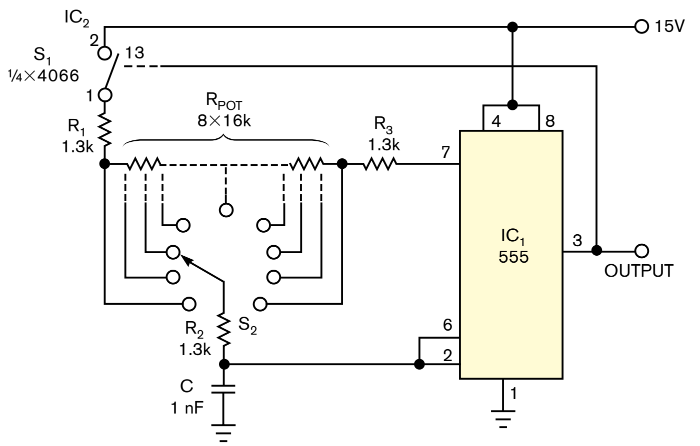

Figure 3 To obtain fixed-duty-cycle values for linearity evaluation, you can replace the potentiometer with a rotary switch and a series-connected string of precision resistors.

To obtain a continuously variable duty cycle, **Figure 2** shows how to connect potentiometer R_4 to the common junction of R_1, R_2, and R_3. The output waveform's duty cycle, D_TC, follows the equation: $D_TC=(R_1+R_2+R_{VAR})/(R_1+2R_2+R_3+R_{POT})$, where R_{POT} is the potentiometer's end-to-end resistance, and R_{VAR} is the fraction of R_{POT} between the rotor and R_1. As the equation shows, D_TC depends linearly on R_{VAR}. Switch S_1 comprises one section of a 4066 CMOS quad bilateral SPST switch, IC_2.

You can use the circuit in **Figure 3** to evaluate duty-cycle linearity. A rotary switch and a tapped series string of 16-kΩ resistors provide a 10-kHz signal with nine discrete, equally spaced duty-cycle values ranging from 2 to 98%. For accurate results, use a 5½-digit multimeter to match the values of resistors R_4 through R_{11} and a Tektronix 3012 oscilloscope or equivalent to gather D_TC data.

Microsoft's (www.microsoft.com) Excel-spreadsheet software includes a linearity analysis that returns the following trend line for the duty-cycle measurements: $D_TC=0.7565\times R_{VAR}+2.1548$; $R^2=1$. The value of 1 for R^2 as Excel calculates shows that the transfer function is perfectly linear. Switch S_1's on-resistance and particularly its leakage current slightly affect the D_TC-versus-R_{VAR} equation's slope and intercept, but the equation remains strictly linear. Using only one of IC_2's four switches eliminates leakage effects and crosstalk that would occur if other circuits used the remaining switches. In addition, using moderately low values for the resistor network further reduces leakage-current effects on circuit performance.EDN

Drive a blue LED from a 3V battery

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Using a blue LED can pose problems when available power-supply voltages don't meet or exceed the LED's 3V forward-voltage drop. This Design Idea shows how to drive a blue LED from a 3V battery or another power supply. The circuit in **Figure 1** uses the On Semiconductor (www.onsemi.com) NCP1729 voltage inverter, IC_1, to produce enough voltage to drive blue LED D_1. Transistor Q_1 serves as a constant-current limiter for the LED's forward current. When current through the LED and R_S increases to a level that develops enough base-emitter voltage to turn on Q_1, Q_1's collector draws current from the voltage divider comprising R_1 and R_2 and forces IC_1 to shut down. The voltage inverter restarts when the voltage drop across R_S falls below Q_1's base-emitter turn-on threshold. Pulling transistor Q_2's base to ground through R_2 turns on the circuit.

In this application, the LED exhibits a voltage drop of approximately 3.3V at 10 mA forward-bias current. **Table 1** illustrates the LED's applied voltage, $V_{BAT}+|V_{OUT}|$, and Q_1's base-emitter voltage for various battery-voltage values.EDN

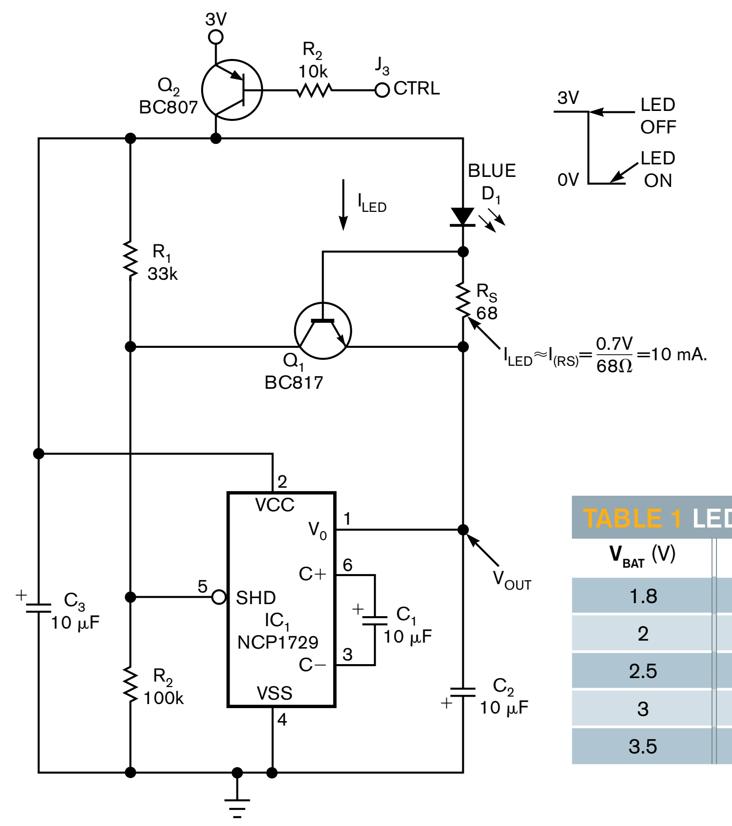


Figure 1 This circuit uses the On Semiconductor NCP1729 voltage inverter, IC_1, to produce enough voltage to drive blue LED D_1.

TABLE 1 LED APPLIED VOLTAGE

V_{BAT} (V)	V_{OUT} (V)	$V_{BE(Q1)}$ (V)
1.8	−1.5	0.41
2	−1.37	0.46
2.5	−0.79	0.42
3	−0.27	0.4
3.5	0.23	0.41

Add simple disable function to a panoramic-potentiometer circuit

Lawrence Mayes, Malvern, United Kingdom

In audio-mixing applications, one frequently required function involves mixing a monaural or single-channel source into a stereo-sound field. Audio engineers refer to a panoramic-potentiometer circuit as a circuit that generates left and right signals of correct amplitudes from a monaural signal and places the signal's image anywhere in a stereo-sound field. For the image's loudness to appear independent of its final position, the derived left and right signals must add to produce a constant-power signal rather than a constant-voltage signal.

The widely used circuit in **Figure 1** performs this function by dividing the monaural signal between the two stereo channels and varying each channel's gain between zero and M such that at R_7's centered position, each channel's gain is 0.707M. If you calculate component values to achieve these conditions, then the circuit presents the remarkable property that, for all positions of R_7's wiper, the sum of the powers in the left and right channels is constant to within 0.19 dB.

You can use a DPDT switch, S_1, to bypass the circuit and thus remove it from the audio chain (**Figure 2**). As an alternative, you can add two resistors and use an SPST switch to disable or enable the circuit. The circuit in **Figure 3** presents the same gain characteristics as in **Figure 1**. Closing switch S_1 enables the panoramic-potentiometer function, and opening the switch produces a fixed central-sound image. Additionally, from a practical viewpoint, the circuit of **Figure 3** simplifies wiring and introduces no significant switching transient because enabling the panoramic-potentiometer function involves only grounding R_7's wiper. Even when you use preferred-value components and disregard component tolerances, the circuit introduces a maximum gain error of only 0.21 dB.**EDN**

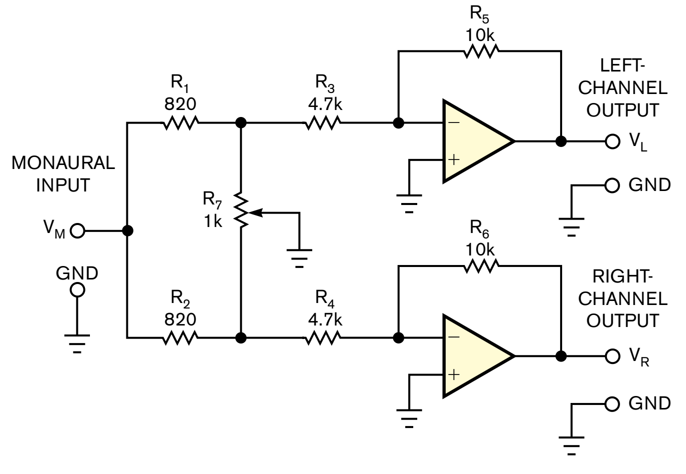


Figure 1 In this basic panoramic-potentiometer circuit, the position of R_7's wiper controls the position of a monaural image in a stereo audio signal.

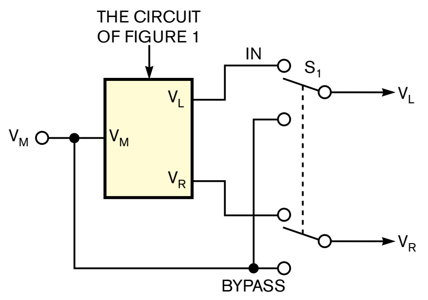
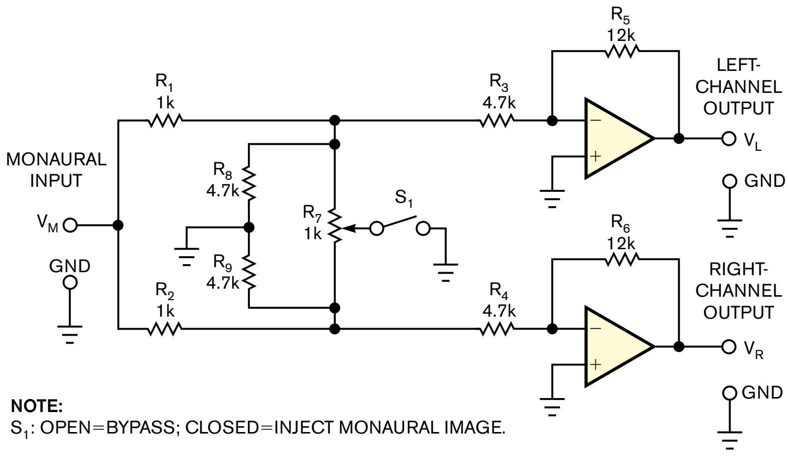


Figure 2 A DPDT switch removes the panoramic potentiometer but introduces wiring complexity and transients.



NOTE:
S_1: OPEN=BYPASS; CLOSED=INJECT MONAURAL IMAGE.

Figure 3 Adding resistors R_7 and R_8 and SPST switch S_1 simplifies wiring and minimizes transients.

Simple single-cell white-LED driver uses improvised transformer

Jim Grant, Scientific Controls, Orlando, FL

A white LED delivers a wide color spectrum and better visibility than do monochromatic LEDs. However, a white LED presents a higher forward-voltage drop than do its colorful counterparts and thus poses problems for operation from a single 1.5V cell. The self-oscillating step-up converter in **Figure 1** features a minimal component count and an easily assembled transformer, T_1.

During the time it takes to charge T_1's primary inductance, resistor R_1 and T_1's added secondary winding provide sufficient base current to turn on Q_2. Q_2's collector current increases until its base current can no longer hold the transistor in saturation. When Q_2 comes out of saturation, T_1's magnetic flux and secondary-voltage polarity reverse. During T_1's primary-discharge interval, the combination of T_1's secondary voltage in series with Q_1's base-emitter voltage applies reverse bias to Q_2's base and turns off the transistor. When Q_2 turns off, the voltage across T_1's primary inductance adds to the battery voltage and applies a forward bias to the LED, D_1. The current through R_1 determines the power applied to the LED and applies forward bias to Q_1's base-emitter junction to provide temperature-compensated bias voltage for Q_2.

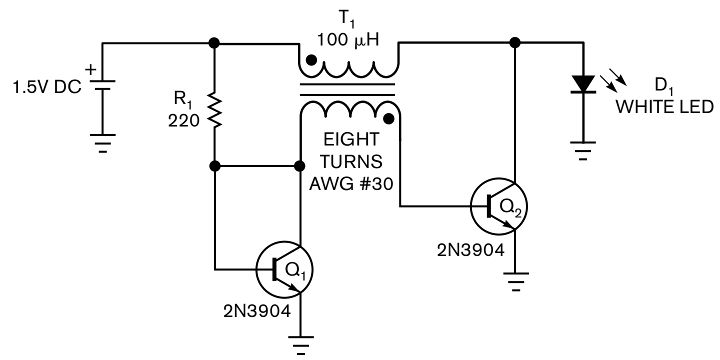


Figure 1 Two transistors and an easily assembled transformer drive a white LED from a single 1.5V battery.

The breadboarded circuit's transformer, T_1, comprises eight turns of AWG #30 insulated wire wound around the body of an unshielded 100-µH axial-lead inductor, producing approximately 400 mV p-p across the secondary winding. (**Editor's note:** Observe the winding's polarity dots. If the circuit fails to oscillate, reverse the connections to either the primary or the secondary winding.) The circuit operates over an input voltage range from just above Q_1's base-emitter voltage drop of approximately 0.6V to the LED's forward-voltage drop of approximately 3V. The circuit's switching frequency exceeds 340 kHz at 1.5V input.**EDN**

Implement a stepper-motor driver in a CPLD

Stephan Roche, Santa Rosa, CA

Based on the Motorola (now Freescale, www.freescale.com) heavily used but obsolete SAA1042 stepper-motor-driver IC, this Design Idea describes a CPLD (complex-programmable-logic-device)-based implementation of a stepper-motor driver that can also replace the driver in SAA1027- or UCN5804B-based designs. The design uses only six macrocells of a Xilinx (www.xilinx.com) XC9536 CPLD and thus can implement multiple stepper-motor drivers in one small-capacity CPLD. The CPLD stepper-motor driver requires clock, direction, step-size, and reset inputs. The clock input accepts logic-level pulses and goes active on the pulse's positive edge.

The direction, or CW/CCW (clockwise/counterclockwise), input determines the motor's rotational direction. Depending on the motor's electrical connections, holding this input at 0V normally produces CW rotation, and a logic-1 input produces CCW rotation. The step-size—that is, full- or half-step—input determines the motor's angular rotation for each clock pulse. Holding this input low commands the motor to execute a full step for each applied clock pulse, and a high input

TABLE 1 DRIVER OUTPUTS FOR EACH MACHINE STATE

Outputs	Step 0	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
A	0	0	1	1	1	1	0	0
A_n	1	1	1	0	0	0	0	1
B	0	0	0	0	1	1	1	1
B_n	0	1	1	1	1	0	0	0

produces a half-step. A high level on the reset input puts the motor in a previously defined state and commands the CPLD to ignore any incoming clock pulses.

The CPLD's outputs comprise A and A_n and B and B_n phases, each of which controls one of the motor's two coils through external power drivers IC_2 and IC_3, which operate at the motor's nominal voltage (**Figure 1**). A pair of Schottky diodes at each driver's output protects the drivers' outputs during inductive-voltage transients induced by reversing the windings' currents. Using MOSFET drivers with internal diodes, such as Microchip's (www.microchip.com) TC4424A dual driver, may eliminate the requirement for external diodes.

The CPLD's program comprises an eight-state Moore finite-state machine that corresponds to the motor's eight half-step states. **Table 1** shows the driver's outputs for each machine state. In full-step state mode, the state machine executes only Step 0, Step 2, Step 4, and Step 6. At each clock pulse's rising edge, the machine state changes from Step(n) to Step(n+1) if CW/CCW is high or from Step(n) to Step(n−1) if CW/CCW is low. You can download a generic VHDL implementation of the stepper-motor-driver firmware from this Design Idea's online version at www.edn.com/070215di2. Although written for an XC9536 CPLD, the code is also suitable for any CPLD or FPGA target device.**EDN**

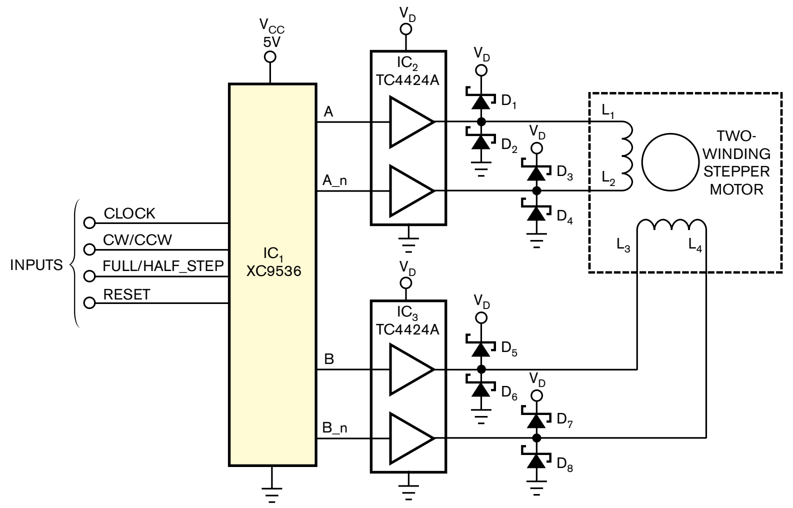


Figure 1 Emulating a dedicated stepper-motor controller, a programmable-logic device, IC_1, applies stepper-motor signals to motor drivers IC_2 and IC_3.