Pre-Warped Drive Signal Reduces Actuator Hysteresis Error

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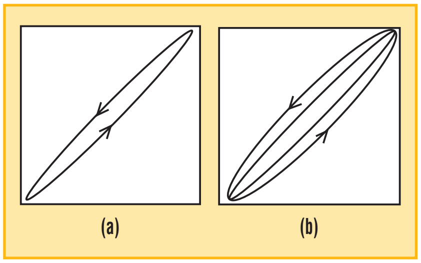
CIRCLE 520

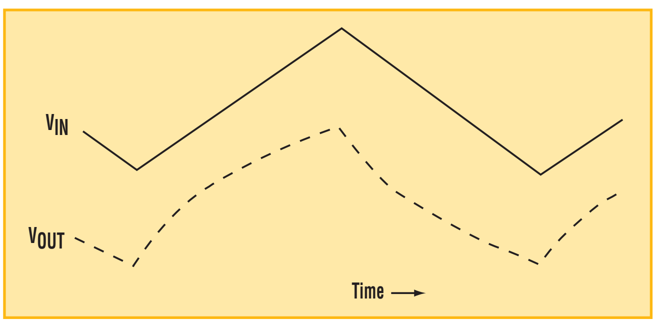
Many displacement transducers exhibit hysteresis in their response to drive signals. To observe this behavior, drive the actuator with a triangle wave while measuring the actuator response with a linear position transducer. Then, display the command and response signals on an X/Y oscilloscope. Figure 1a depicts the familiar lenticular hysteresis display at a low-repetition frequency.

Typically, an actuator with such response exhibits more hysteresis as the triangle-wave frequency is increased. If we could superimpose the trace at a higher frequency over the low-frequency trace, we would see a display such as that depicted in Figure 1b.



1. The actuator hysteresis at low frequency (a) increases at higher frequencies (b).

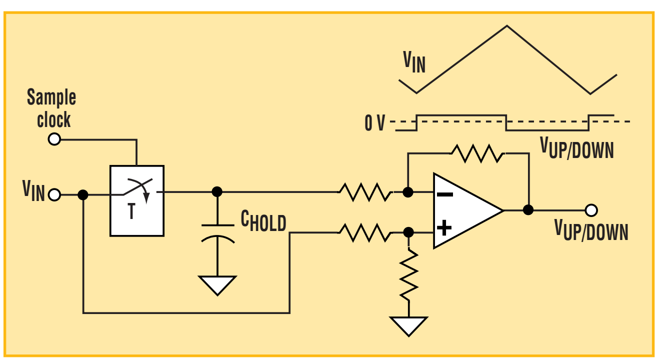
Since this actuator response to a triangle-wave input can be measured in advance, a nonlinear drive signal can be generated to compensate for the response. This is achieved by making an amplifier that has approximately the opposite response to the triangle-wave input. Driving the actuator with the properly warped signal makes the position-displacement response more linear with respect to the triangle-wave input signal. For the triangle-wave input signal, V_{IN}, the desired drive signal, V_{OUT}, is determined as shown in Figure 2 (dashed line).



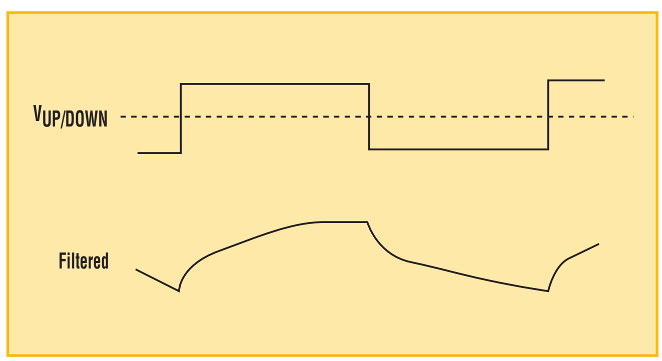
2. Driving the actuator with the properly warped signal, V_{OUT}, makes the position-displacement response more linear with respect to the triangle-wave input signal.

The required signal has a different response to rising input voltage than it does to falling input voltage. This suggests a straightforward circuit implementation. If a delayed version of the input signal is subtracted from the present value of the input signal, a signal $V_{UP/DOWN}$ can be established that is proportional to the input dv/dt. With a sample/hold amplifier and a difference amp, a ΔV signal can be produced. Figure 3 depicts an appropriately scaled version of $V_{UP/DOWN}$ for a triangle-wave drive signal. Adding a scaled and low-pass-filtered output of $V_{UP/DOWN}$ to the original triangle wave produces a warped drive signal *(Fig. 4)*.

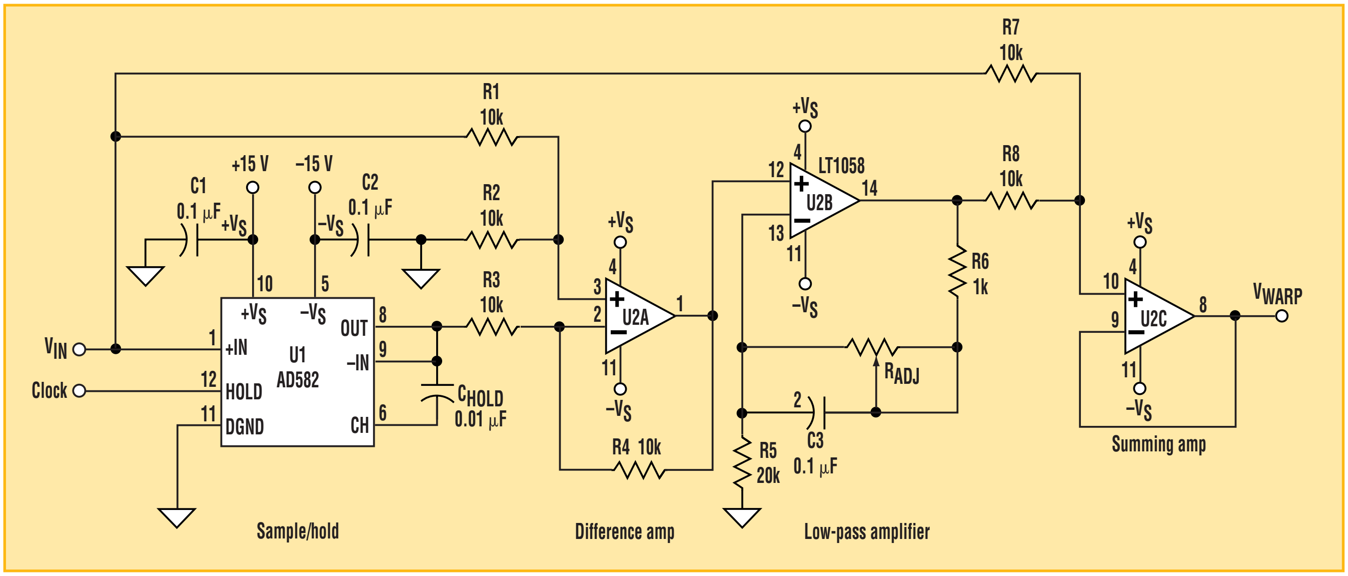
Operation of the sampler at a fixed clock rate means that as the frequency of the example triangle wave increases (or as the slew rate of any drive signal increases), so too does the amplitude



3. With a sample/hold amplifier and a difference amp, a ΔV signal can be produced to help create the warped drive signal.



4. Adding a scaled and low-pass-filtered output of $V_{UP/DOWN}$ to the original triangle wave produces the desired warped drive signal.



5. The full schematic of the pre-warp circuit includes a simple first-order low-pass filter for $V_{UP/DOWN}$.

of $V_{UP/DOWN}$. Therefore, the warping increases with frequency in a manner appropriate to compensate for the increasing actuator nonlinearity.

For the first breadboard version of the pre-warper, a simple first-order low-pass filter was selected for the $V_{UP/DOWN}$ filter. The breadboard schematic can be seen in Figure 5.

Low-Cost Digital Thermometer Uses Single-Chip Microcontroller

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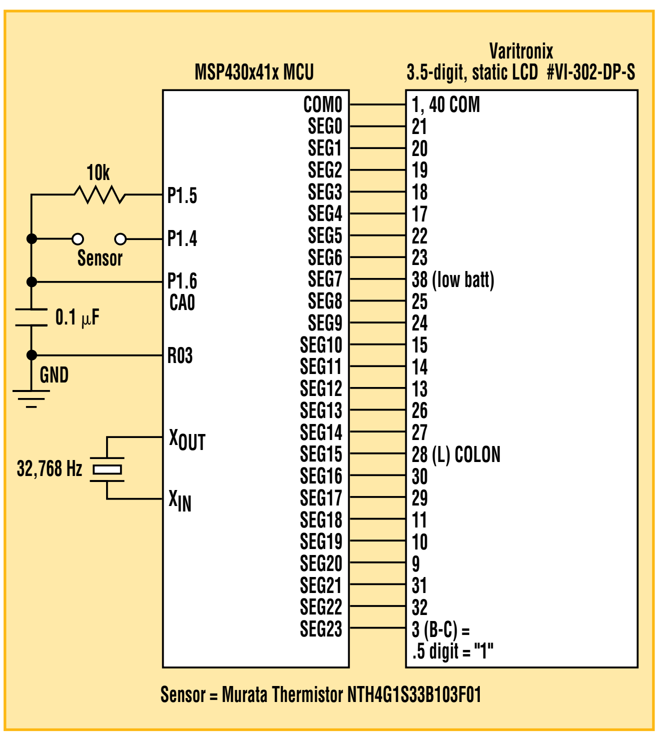
CIRCLE 521

In many applications, the ability to read and display temperature is either desirable or an absolute requirement. Some of these applications include temperature probes, thermostats, CPU monitors, and process-control equipment. The figure illustrates a simple system for reading and displaying the temperature. This circuit requires only one microcontroller (MCU), as opposed to other solutions that need separate power management and analog converter chips. Moreover, the circuit doesn't require any special treatment of the reset pin because the MCU used incorporates brown-out detection.

The MSP430F412 MCU from Texas Instruments executes the code from flash memory while being clocked from a high-speed internal oscillator. First, the code reads the resistive sensor using the single-slope analog conversion technique. Then, the reading is converted to a BCD value and displayed on the LCD. The LCD doesn't re-quire a separate driver chip; it's directly driven by the MCU. Also, the LCD displays a flashing "F" to indicate that the reading is in degrees Fahrenheit, and that the circuit is actively reading the temperature.



This simple digital thermometer uses one MCU to read a thermistor-type sensor using single-slope analog conversion. The reading is then displayed on an LCD driven directly by the MCU.

Once the display is updated, the MCU enters low-power standby mode. During this time, only an internal timer is active and being incremented by the 32-kHz crystal. This timer controls the framing frequency of the LCD so that it remains on, displaying the last temperature reading. After a software selectable time delay, the same timer generates an interrupt. The interrupt then restarts the CPU and internal high-speed oscillator, and the whole process repeats. Each cycle of the interrupt either clears or writes the "F" to the display, causing it to flash.

The MSP430F412 is specifically designed for low-power battery-based applications. As a result, while the MCU is in standby mode with the LCD on, the entire circuit only draws about 1.5 µA. Because the MCU has extremely fast startup and shutdown times, it can spend more than 97% of its time in standby mode. When the circuit is in active mode or measuring the sensor, it draws only an average current of 110 µA. Combining the long standby time and the short active time results in an overall average current of under 5 µA for the circuit. If the circuit were powered from a 220-mAh, 2032-type coin cell, it could operate continuously for up to five years between battery changes.

The digital thermometer task requires only a small fraction of the MCU's resources. The program uses less than 17% of the flash memory. There are 21 I/O lines available for other uses, and the CPU is off at most times. With these facts in mind, it's easy to see how the digital thermometer could be just a small part of a more complex application implemented on the same MCU. The thermometer could be a subfunction of a circuit that controls production equipment, changing the speed and power based on the temperature reading.

Or instead, it could be the heart of a digital thermostat that also reacts to the time of day, as the 32-kHz input directly divides down to provide a real-time clock. The thermometer could even be part of a datalogging system that uses the MCU to store the data and run the code. This is possible because the MSP430F412 can write to its own flash memory.

The code listing used in this application can be downloaded from *www.PlanetEE.com.*

Detect Loop-Reverse Battery Conditions On A Telephone Line

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CIRCLE 522

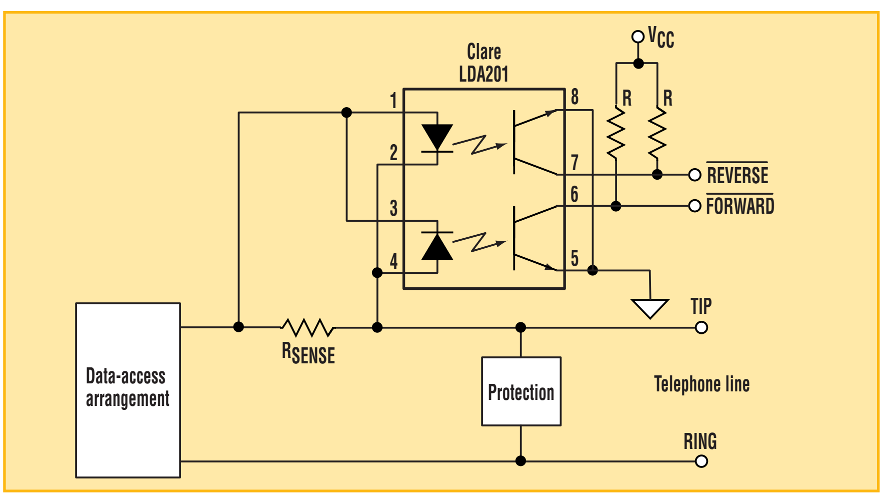
Equipment connected to the public switched-telephone network (PSTN) sometimes needs to detect polarity reversals of the battery feed. One common application is the Direct-Inward-Dialing (DID) service that uses what is termed as "loop-reverse battery signaling." For more details on the implemention of DID, refer to ANSI document T1.405-1996. One of the requirements for DID operation is that the telephone-line loop current be monitored for current direction. The direction of current is directly related to the battery polarity applied to the circuit. One possible implementation uses a Clare LDA201 dual optocoupler *(www.clare.com)* as a solid-state current sensor *(see the figure)*.

Normally, TIP is positive with respect to the RING lead on the telephone line. The nominal open-circuit voltage from the PSTN is 48 V. R_{SENSE} is selected such that a particular threshold current can be set before the reverse or forward signal is asserted. For example, suppose you want to make the current detection occur when the loop current is ≥10 mA. Using the typical value for V_F in the LDA201 data sheet:

$$R = V_F/I$$

$$R = 1.2/10 \text{ mA} = 120\ \Omega$$

With R_{SENSE} set to this value, the FORWARD line will activate when the loop current exceeds 10 mA. If TIP and RING polarity is reversed, the REVERSE line will activate when the loop current is greater than 10 mA. Note that 1.2 V is the typical value for V_F. If we take into account the minimum and maximum V_F (0.9 V and 1.4 V respectively), the detection threshold can vary from 7.5 to 11.7 mA with a 120-Ω resistor. Also, V_F changes with temperature as shown in the characteristic curves from the LDA201 data sheet. Pull-up resistors, R, should be selected based on the minimum current-transfer ratio (CTR) specified in the data sheet, and the minimum LED current for the application. Note that the LEDs in the LDA201 are rated for a maximum current of 100 mA, so series-limiting resistors for the LEDs are unnecessary.



Based on a dual optocoupler, this circuit can detect battery-feed polarity reversals on the public switched-telephone network.