

A new approach of digital potentiometers: digital impedance measurements

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Abstract- Digital potentiometers offer a low-noise, stable, reliable and simple alternative to digital to analog converters (DACs) and mechanical potentiometers. This paper is about the importance of digital potentiometers and the possibility of implementing them in digital impedance measurements. Here is also shown the possibility of digitizing of an analog bridge fated to impedance measuring. It is possible due to existence of digital potentiometers and their usage in measurement scheme.

I. Introduction

Impedance is the most important parameter used to characterize electronic circuits, components, and materials used to make components. Different impedance measurement techniques, such as oscillators, frequency domain techniques, and digital AC bridges, etc., have been developed in the last decades to satisfy the increasing requirements. Nowadays, all new methods of any measurement are digital. Even if the old analogical methods offer good accuracy and resolution, they are no more up to day and are transmuted in digital. Nowadays, a large variety of methods for digital impedance measurements exist, but it always will be an open domain for future work [1].

Digital potentiometers are electronic digitally-controlled devices which provide some powerful application advantages. Additionally to other advantages, since the device is silicon-based, it is insensitive to mechanical vibrations, shock and oxidation, making it a higher reliability alternative to mechanical potentiometers across most environmental conditions.

Nowadays, a digital potentiometer (digipot) family with the industry's best resistor tolerance, allowing designers of industrial and instrumentation equipment to meet tighter resistor matching requirements for improved system accuracy was introduced. In industrial control systems, medical instrumentation, and other devices that require finely tuned gain and offset control, power supply calibration or volume control, the tighter resistor matching provided by the new digipots allows engineers to set the range with greater accuracy, resulting in more precise system controls. There is a wide variety of possible functions that can be implemented using the variability of the digipot in conjunction with standard active devices like operational amplifiers and comparators.

A digipot performs the same electronic adjustment function as a mechanical potentiometer with enhanced resolution, solid state reliability, and remote controllability. Due to digipot we can command and control an ordinary bridge for impedance measurement. In this way we can use both the advantages of simple bridge for impedance measurement and of digital potentiometer.

II. Digital potentiometers

Digital potentiometers facilitate digital control and adjustment of resistances, voltages, and currents in analog circuitry. Common applications include power supply calibration, audio volume control, brightness control, gain adjustment, and control of bias and modulation currents in optical modules.

Beyond basic digipot specifications, there are a number of features that can improve system performance and simplify designs. Among these features are various types of nonvolatility, zero-crossing detection, debounced pushbutton interfaces, temperature compensation, and write protection. The relevance of each of these features varies with the application.

A digital potentiometer adjusts and trims electronic circuits similar to variable resistors, rheostats and mechanical potentiometers. Sometimes called digital POT, RDAC, or digipot, these compact devices can be used to calibrate system tolerances or dynamically control system parameters.

Put simply, a digipot is an analog output controlled by a digital input. This description is similar to the definition of a D/A converter. Unlike D/A converters, which provide a buffered output, most digipots are not intended to drive low impedance loads without an external buffer. Many similarities of DACs and digipots allow one to use both device types in some applications [2].

Similarities between DACs and digipots:

Digipots offer the same basic function as do DACs. If the low terminal of a digipot is connected to ground, it operates as a voltage DAC but with high output resistance, and has the same transfer function as a DAC. That connection allows a digipot with output buffer to be used as a voltage DAC, as shown in Figure 1.

Digipots and DACs are also available as nonvolatile devices, which mean they retain their digital input value when the supply voltage is removed. Because digipots and DACs are often used to “calibrate out” the non-ideal characteristics of an analog signal path (offset and gain, for example), these input compensation values should not be lost during a power failure or system restart. Despite the DAC’s lack of an L terminal, the DAC has features that are precluded in a digipot due to its inherent structure.

Differences between DACs and digipots:

The number of wiper taps on a digipot is limited by layout and technology restrictions. A high-end digipot might have 1,024 taps, equivalent to a DAC with 10-bit resolution, but DACs are currently available with resolutions of 24 bits and more.

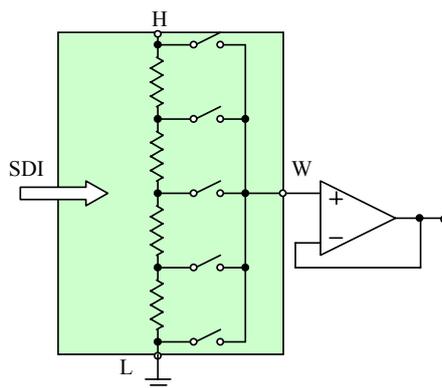


Figure 1. A digipot used as a voltage-output D/A Converter requires an output buffer amplifier

The tap spacing of today’s digipots can be linear or logarithmic. Logarithmic potentiometers are commonly used for controlling audio volume. By compensating for the nonlinear relationship between voltage and the perceived sound intensity, they produce an apparent linear relationship between knob position and sound level. Linear multiplying DACs can also be used to achieve a nonlinear relationship between SDI and V_w , but they need higher resolution for that purpose. Because DACs with higher resolution are more expensive, logarithmic digipots tend to be more popular.

Digipots generally support only relatively slow signals, but DACs can pass and generate extremely fast signals. DACs are often used for fixed or slowly varying voltage generators, while specialized DACs are also available for high-speed and RF applications.

The output impedance of a voltage-output DAC is small and fairly constant, whereas the output resistance of a digipot is much higher, and varies strongly with the wiper setting. The output resistance of a common 100-k Ω digipot, for example, ranges from about 100 Ω to a maximum of 50 k Ω .

Because digital pots are set with upward/downward pulses or via a serial interface, they require few pins and usually come in small packages. Slow DACs often come in small packages for the same reason. A fast DDS DAC, on the other hand, has parallel pins for fast data loading, and therefore resides in a larger package.

III. Virtual measurements

Virtual instrumentation (VI) is the use of customizable software and modular measurement hardware to create user-defined measurement systems, called virtual instruments. It is specialized to simulate the characteristics and performance of an instrument or a system for measuring, testing or data recording [3].

The virtual instruments can turn the computer into a "command server" of a network of measuring devices able to communicate through a specific protocol [4]. Thus, connecting measurement devices to a computer and implementing the specialized software we can command all this devices, namely we command taking, recording and processing results. In this way a laboratory can be brought one step higher in performance.

Comparing to the classic measuring system, the difference is that all functions of data processing and analysis, the storage of this information and transmitting of this to the human user are made by computer and not by dedicated devices.

Thus, such software can replace roughly 80% of circuits of a classic measuring or testing specialized device. Software that performs these functions has in most cases a graphical interface with the same look as the front panel of a measuring device. That is why the applications are called Virtual Instruments.

IV. Digital potentiometers in digital impedance measurements

Starting with the analog Grützmacher bridge [5] and the concept of virtual impedance measuring was developed a new system for digital impedance measurement. The configuration of Grützmacher bridge consists of a simple resistor, two potentiometers and the unknown impedance. In new scheme the resistor and one of the potentiometers are modelled by proper software, and the second potentiometer is replaced by a digipot. Thus due to existence of digital potentiometers and their usage in measurement scheme it was possible to obtain a fully digitized automatic bridge for impedance measurement, Figure 2.

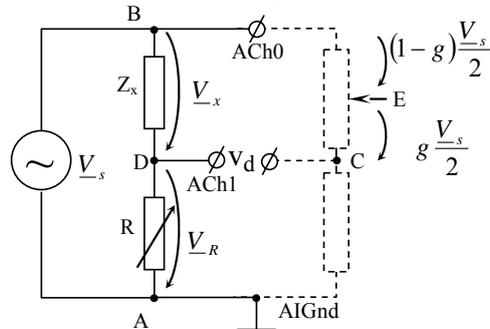


Figure 2. Virtual Grützmacher bridge.

The signal generator employed, Tektronix AFG310, supplies the series circuit formed by the unknown impedance, Z_x , and the digital potentiometer R with an accurate sinusoidal waveform. The voltage supplied, \underline{V}_s , along with the voltage drop across the resistor, \underline{V}_R , are acquired using the two analogue channels of a simultaneous sampling DAQB type PCI-6111 manufactured by National Instruments. The maximum sampling frequency allowed is 5 MHz. The software part of the virtual instrument is entirely built in the graphical programming environment, LabVIEW 8.2.

The operations performed by this instrument are: i) driving the acquisition process of the voltages \underline{V}_s and \underline{V}_R on the simultaneous sampling analogue channels of the DAQB, ii) sending the command instruction codes to digital potentiometer, iii) performing two balances of the bridge, iv) calculating the absolute value and phase of the unknown impedance, v) saving the information at request.

For measuring the absolute value of unknown impedance is considered only the real half of the bridge. In this case the circuit consists of the impedance in series with the potentiometer supplied by the signal generator. For measuring of absolute value of impedance has to be accomplished the next condition: $V_{x\max} = V_{R\max}$, where $\underline{V}_x = \underline{V}_s - \underline{V}_R$ is obtained soft. This operation is possible due to the fact that ACH0 and ACH1 are simultaneous sampling analogue channels of the DAQB. The value of potentiometer R is modified until the above condition is satisfied with a required accuracy. As a result of this operation $|\underline{Z}_x| = R$ is obtained. All the measurement tasks including the potentiometer adjustment are automatically executed and driven by software developed in LabVIEW, using a minimal interface consisting in a data acquisition board. The value of the digital potentiometer is modified by sending the proper code to SDI in order to minimize the difference between $V_{x\max}$ and $V_{R\max}$.

For phase measurement, the following operations are performed [5]:

- ◆ the voltages $|\underline{V}_{DC}| = \left(v_D - \frac{v_s}{2} \right)_{\max}$ and $|\underline{V}_{EC}| = g \frac{V_{s\max}}{2}$ are equalized by modifying g , where $0 \leq g \leq 1$, fig. 2.
- ◆ next calculus can be accomplished by soft:

$$\operatorname{tg} \frac{\varphi_x}{2} = \frac{|\underline{V}_{DC}|}{|\underline{V}_{AC}|} = \frac{g \frac{V_{s\max}}{2}}{\frac{V_{s\max}}{2}} = g \Rightarrow \varphi_x = 2 \operatorname{arctg}(g)$$

In this way, polar components of the unknown impedance are obtained.

V. Conclusions

Using a digital potentiometer was obtained a measurement scheme which can compensate inconveniences of the classical bridge and in the same time can take the advantage of a computing system. Using a digipot not only avoids the inefficiency and mechanical durability concerns of a mechanical potentiometer; it actually conserves power and increases efficiency.

The performances of digipots are increasing with time. It means that this measurement method can be improved by technological changes.

We can mention that the method which uses a digipot is good enough for laboratory use, especially for that which can not afford a quite expensive RLC-meter, but has a computer, the suited software and data acquisition device. The originality of this method consists in fact that here were combined the advantages of analog measurement and new digital techniques.

References

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