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A Proposed Resistance-to-Time Converter with Switching Impulse Calibrators for Application in Resistive Bridge Sensors

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ABSTRACT

This paper presents a simple resistance-to-time converter. It consists of two voltage comparators, a ramp voltage generator, two logic gates and impulse voltage calibrators. A square-wave generator circuit is suggested in this paper. The design is simple and independent of the OPAMP offset issues. The resulting square-wave is rectified to get its DC equivalent and to a triangular output; the two outputs are applied to a comparator for generating a digital output with a duty cycle proportional to a change in resistance upon which is dependent the DC.

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1. INTRODUCTION

An impulse voltage generator produces very short high- voltage or high-current surges. This type of devices can be found into two types: impulse voltage generators and impulse current generators. High impulse voltages are used to test the strength of electric power equipment against lightning and switching surges. In addition, the microprocessors in measurement systems require transducers with digital outputs. This is true of a low cost and high accuracy pressure and acceleration measuring system using resistive bridge sensors. The simplest approach of converting the bridge resistance deviation into a digital form is to convert the unknown resistance to frequency or time interval.

Resistance-to-frequency conversion is mainly based on a relaxation oscillator [1, 2], which consists of a resistive bridge followed by an analogue voltage differentiator (i.e., a differential amplifier or differential integrator). On the other hand, resistance-to-time conversion is based on pulse-width modulators [3] or current-tunable Schmitt triggers [4]. The former consists of a resistive bridge followed by pulse-width modulators and a digital time differentiator, while the latter by voltage-to-current converters, current-tunable Schmitt triggers, and a digital time differentiator.

This paper describes a new resistance-to-time converter, which is believed to be most simple in its configuration and operation. It requires two voltage comparators, a ramp voltage generator, and a digital time differentiator. The simplicity of the converter makes it suitable for implementing in ‘smart sensor’, which gives a digital output directly connectable to a microprocessor

2. CIRCUIT DESCRIPTION AND OPERATION

Figure 1 shows the circuit diagram of the resistance-to-time (R-to-T) converter for interfacing resistive bridge sensors. It consists of a ramp voltage generator, a resistive sensor bridge with four sensors, two voltage comparators, and two logic gates. The impulse voltage generator is connected to the point denoted by V_{int}. The output of NOR gate gives the continuous pulses to the calibrators.

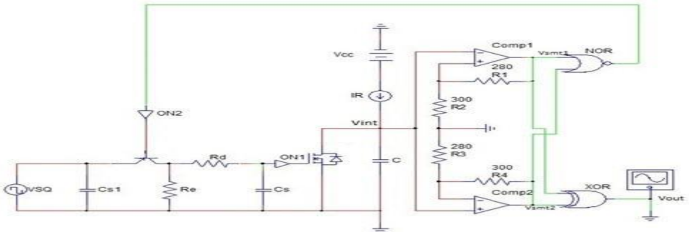

Figure 1. Circuit Diagram of the Resistance-to-Time Converter

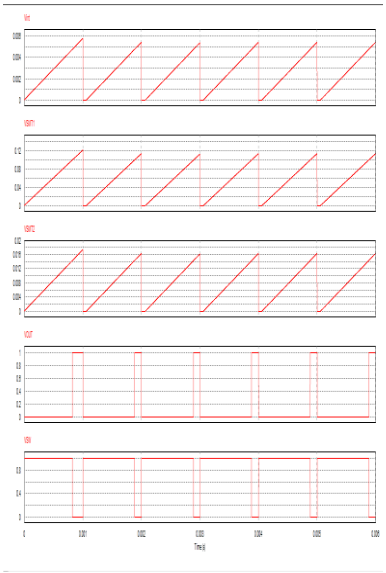

Figure. 2. Voltage Waveform at Various Nodes of the Converter.

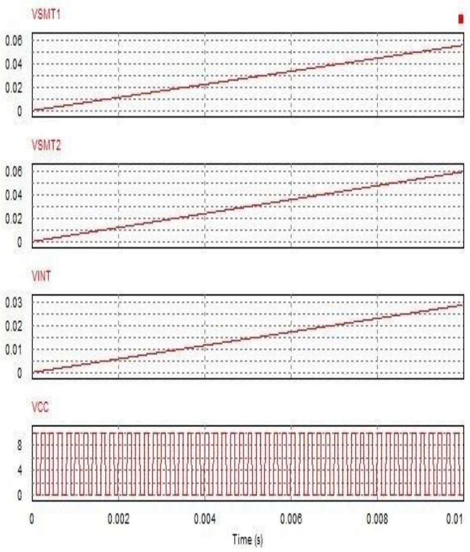

Figure. 3. Voltage Waveform at Various Nodes of the Converter.

The comparator 1 and the upper half bridge form Schmitt trigger whose threshold voltage is given by [5]

$$V_{TH1} = \left(1 - \frac{\Delta R}{R}\right)\frac{L_{1+}}{2} \tag{1}$$

Similarly, the comparator 2 and the lower half bridge form Schmitt trigger whose threshold voltage is given by [7]

$$V_{TH2} = (1 + \frac{\Delta R}{R})\frac{L_{2+}}{2} \tag{2}$$

Where ΔR represents the change in resistance of the sensors and L_{1+} is the output saturation voltage of the comparator 1, L2+ is the output saturation voltage of the comparator 2. Note that V_{TH1} and V_{TH2} are proportional to the resistance change 1 − ΔR/R and 1+ ΔR/R, respectively.

3. EXPERIMENTAL AND RESULTS

In this work, to see how the R-to-T converter operates, one may refer to Figure 2, which shows the signal waveforms at the various nodes of the converter, and assumes that both Schmitt triggers are at their positive saturation levels (L_{1+}, L_{2+}) and the bridge is unbalanced.

Prior to the start of the conversion cycle, the FET (ON1) is switched ON, thus discharging the timing capacitor C of the ramp integrator and setting the input voltages of the Schmitt triggers V_{INT} to 0 V. The conversion started when the FET(ON1) is switched OFF Since the reference current IR flows through the capacitor, V_{INT} rises linearly with a slope of IR/C. When V_{INT} reaches the high threshold voltage of the upper Schmitt trigger V_{TH1}, the output of the upper Schmitt trigger V_{SMT1} falls to zero and the output of the XOR gate V_{OUT} becomes high. Denoting t1 the time duration for which V_{SMT1} keeps L_{1+},
we can write [6]

$$t_1 = \frac{C}{IR} V_{TH1} = \frac{C}{2IR}\left(1 - \frac{\Delta R}{R}\right) L_{1+} \tag{3}$$

The conversion process continues until VINT reaches the high threshold voltage of the lower Schmitt trigger V_{TH2}. At this instant, the output of the lower Schmitt trigger V_{SMT2} falls to zero, thereby V_{OUT} becomes low and the output of the NOR gate VSW becomes high. The ramp integrator is switched OFF and clamped the voltage V_{INT} to ground. This, in turn, triggers the Schmitt triggers, causing their outputs rise to L_{1+} and L_{2+}, respectively, and V_{SW} goes to low. The ramp integrator is switched ON after the fixed duration T0 of the impulse calibrator and a new conversion process is started. Denoting t_2 the time duration for which V_{SMT2} keeps L_{2+}, we can write, [8]

$$t_2 = \frac{C}{IR} V_{TH2} = \frac{C}{2IR} (1 + \frac{\Delta R}{R}) L_{2+} \tag{4}$$

The time interval of V_{OUT} pulse is given by [8],

$$\Delta t = t_2 - t_1 = \frac{C}{2IR}\{\left(1 + \frac{\Delta R}{R}\right) L_{2+} \left(1 - \frac{\Delta R}{R}\right) L_{1+}\} \tag{5}$$

If the comparators are identical, then $L_{1+} = L_{2+} = L_+$ and Δt is simplified to,

$$\Delta t = \frac{C}{IR}(\frac{\Delta R}{R}) L + \tag{6}$$

Equation (6) indicates that the converter offers an equivalent output pulse whose time interval is proportional to the resistance change. If L_{1+} is not equal to L_{2+}, the output can be expressed as follow: [6]

$$\Delta t = \frac{C}{2IR}(L_{2+} - L_{1+}) + \frac{C}{2IR}\left(\frac{\Delta R}{R}\right)(L_{2+} + L_{1+}) \tag{7}$$

Examination of this result indicates that there is an offset error produced by differences of comparators. The ΔR is the change in the resistance of the resistive bridge sensors. Whenever changing the values of ΔR affects the calibrators.

4. CONCLUSION

This circuit converts a resistance change in the bridge into its equivalent time interval change. It is proven that the design principle and the circuit configuration are simple. Besides these, the converter features good linearity in its conversion characteristics and high accuracy in the low-power supply voltages. These properties make the converter suit for implementing the smart sensors using the resistive bridge sensors. Referring to (6), the time interval (Δt) depends merely on the capacitance, resistance and current of the voltage generator, besides the saturation voltage of the comparator. By the advancement in the semiconductor technology, it is easy to find the identical comparators. The identical comparators ensuring high accuracy and validate (6).

Further, the integrator can be replaced by the microprocessor. The microprocessor replaces the task to switch ON and OFF the voltage generator. Reduces the components count and possibly improves the accuracy of the resistance-to- time converter.

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