MICROPROCESSOR CONTROLLED CONSTANT POWER DELIVERY

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ABSTRACT. A microprocessor-based system for monitoring power delivery is presented. The system ensures constant power delivery to a resistive load. The system implementation requires an 8085 microprocessor, a digital-to-analog converter (DAC), an analog-to-digital converter(ADC), commercially available operational transconductance amplifiers (OTAs) and operational amplifiers.

1. INTRODUCTION

In many industrial applications it may be necessary to keep the power delivered to a load constant irrespective of the variations in the load itself. Of particular interest here are remotely controlled systems where manual adjusment of the power delivery is impossible. In this paper we propose a microprocessor-based system which can take care of the load by making sure that constant power is delivered to it.

2. PROPOSED SYSTEM

The proposed system consists of six major hardware blocks; see Fig. 1. First the load voltage and current are measured. A multiplier is used to obtain an output voltage proportional to the actual power delivered to the load. An analog-to-digital converter (ADC) obtains the digital equivalent of the actual power delivered to the load. This digital word is applied to the input port of the microprocessor where it is compared with another digital word which represents the power required to be delivered to the load. If the two digital words are not equal, then a difference signal will be outputted by the microprocessor. This output digital signal is used to control the resistance of an operational-transconductance-amplifier(OTA)-based digitally programmable floating resistance. The procedure is repeated until the actual power delivered to the load becomes equal to the required power.

3. PRACTICAL REALIZATION

Figure 2 shows the practical implementation of the proposed system. The digitally programmable resistor is realized using the operational transconductance amplifier(OTA)-based circuit shown in Fig. 3 [1]. The input-output relationship of an ideal OTA can be described by

$$i_o = g_m v_{input} \tag{1}$$

where v_{input} is the differential input voltage , $g_m = I_{ABC}/2V_T$ is the transconductance and i_o is the output current, I_{ABC} is the auxiliary bias current of the OTA and V_T is the thermal voltage. Assuming identical OTAs, the input resistance, between points X and Y, of the circuit shown in Fig. 3 can be described by

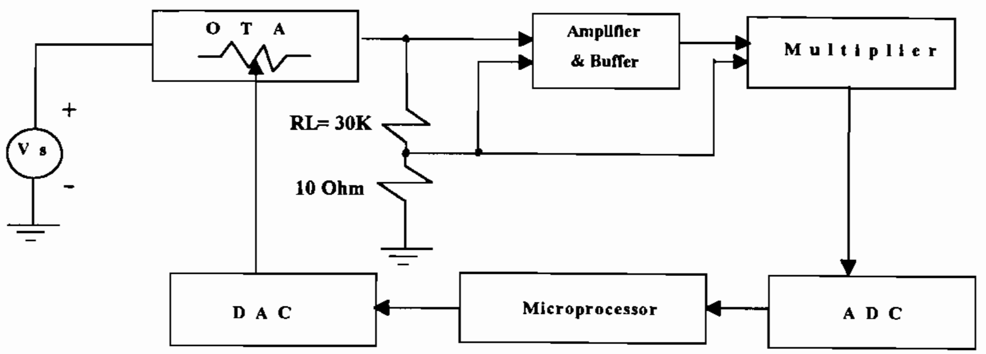

Fig. 1. System layout

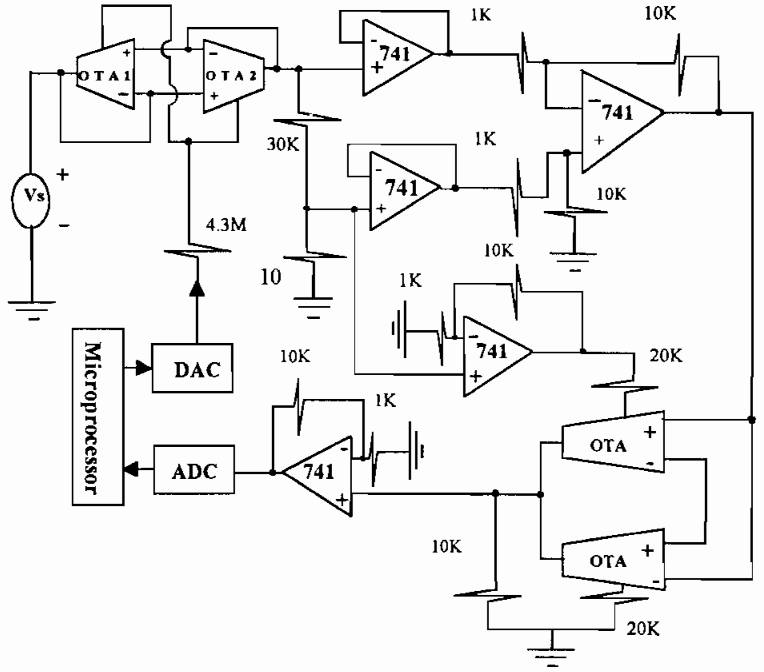

Fig. 2. System Practical Implementation

$$R_{input} = 1/g_m = 2V_T/I_{ABC} \tag{2}$$

From (2) one can see that the equivalent resistance of the structure of Fig. 3 is a function of I_{ABC}. Thus by controlling the current I_{ABC} one can control the equivalent resistance of the circuit of Fig. 3. This current can be obtained from the output of a digital-to-analog converter (DAC). This opens the way for digital programming of the equivalent resistance.

The multiplier is realized using the OTA-based structure shown in Fig. 4 [2]. Assuming ideal, identical OTAs, routine analysis shows that the output of the circuit of Fig. 4 can be expressed by

$$v_o = k v_{input} v_b \tag{3}$$

where $k = R_a/2V_T R_b$. Thus the output of the circuit of Fig. 4 will be proportional to the multiplication of the the two input voltages. If one of the voltages represent the load current and the other represents the load voltage, then the output of the multiplier represents the load power. Note that the output can be appropriately scaled by the factor k.

The proposed system was implemented for providing constant power delivery for the load resistance $R_L = 30k\Omega$. The load current is sensed by measuring the voltage drop across the series-connected 10Ω resistor. This resistance is much smaller than the load. Buffers are used to isolate the load. A differential amplifier is used to provide an output voltage proportional to the voltage across the load only. Since the voltage across the current-sensing resistor is very small, the 741 operational-amplifier may not be suitable and a low-offset operational amplifier may be needed. Here we use the 725 instrumentation amplifier. The output of the multiplier is amplified by a non-inverting amplifier to provide the input of the analog-to-digital converter(ADC).

The sampling time can be divided into two intervals; the time required by the ADC (T_{ADC}) and the DAC (T_{DAC}) to convert the signals and the processing and decision time (T_{pd}). T_{ADC} is the conversion time of the ADC plus the input instruction time ($\cong 30\mu$sec). T_{DAC} is the conversipon time of the DAC plus the output instruction time ($\cong 35\mu$sec). The processing and decision interval T_{pd} takes about 20-40 clock cycles at a clock frequency 2 MHz. This depends on whether we have to update or not. The total sampling time is, threfore,
$T_{ADC} + T_{pd} + T_{DAC} \cong 30 + 10(20) + 35 = 75(85)\mu\,\text{sec}$
Thus the system can respond to fast changes in the power delivered to the load.

The proposed circuit uses the 8085 microprocessor. Figure 5 shows the flow-chart of the program used to monitor the constant power delivery to the $30k\Omega$ load. The output of the microprocessor is applied to the 8-bit DAC0800. The output of the DAC is fed to the auxiliary-bias-current input of the OTAs. The LM13600 OTAs were used for realizing the digitally programmable resistor and the multiplier. Because of the limited input voltage capabilities of the bipolar 13600 OTA, only small powers, of the order of few mW, can be handled. Higher power levels can be handeled by using other OTAs with larger input-voltage and output-current capabilities; for example using CMOS or BiCMOS OTAs. The results show that the system can maintain the power delivered to the load at a predetermined value within limits decided by the system resolution which is mainly determined by the number of bits of the DAC.

4. CONCLUSION

In this paper a microprocessor-based system for monitoring constant power delivery to a resistive load has been presented. Extension of the system to provide constant power delivery to a reactive load is straightforward and simple. In addition to measurements of the amplitudes of the load

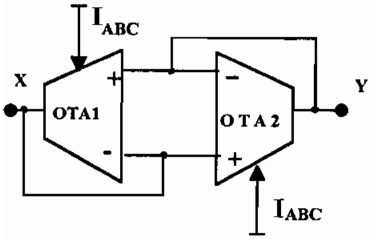

Fig. 3 OTA as a variable resistance

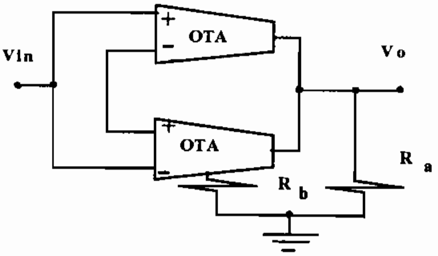

Fig. 4 Multiplier

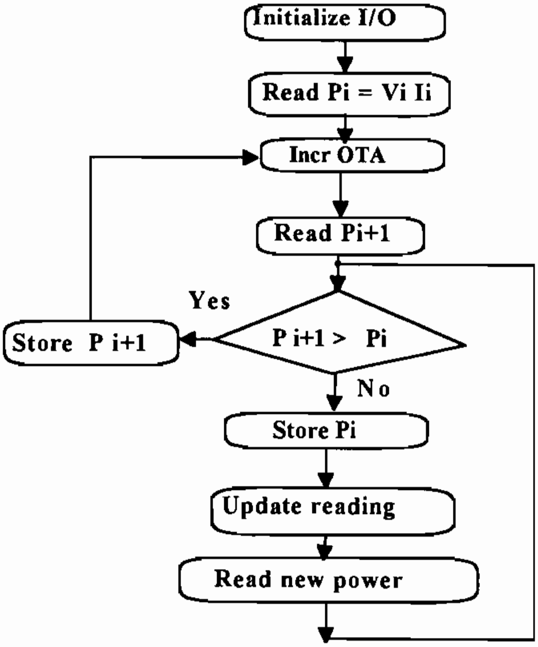

Fig. 5 Program flow-chart

current and the load voltage, this requires a measurement of the phase angle between them, calculation of the cosine of this angle, and multiplying result by the amplitudes of the current and voltage. This can be easily achieved by using an additional multiplier. This will result in an output proportional to the power delivered to the load.

It is worth mentioning here that the microprocessor-based system described can be replaced by a single-chip microcontroller-based system. The microcontroller has built-in ADC, RAM, EPROM and EEPROM. Such implementation will drastically reduce the hardware requirements. Moreover by using 10- or 12-bit DAC higher resolutions can be attained.

ACKNOWLEDGEMENT

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