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A Micro-Controller based dB Meter

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A dB meter is used to compress the large dynamic range of a signal. A logarithmic amplifier based on the exponential *v-i* characteristic of a p-n junction can be used for dB conversion. However, the p-n junction is too sensitive to temperature variations and, therefore, requires temperature compensation. In the proposed dB meter, we use an exponential waveform which does not depend upon the device parameters. The effect of temperature variations in RC values is eliminated by using a well-regulated reference source.

Indexing terms: dB meter, Micro-controller applications, Electronic instruments.

A dB meter is used to compress the large dynamic range of a signal. A logarithmic amplifier based on the exponential *v-i* characteristic of a p-n junction can be used for dB conversion. However, the p-n junction is too sensitive to temperature variations and, therefore, requires temperature compensation [1]. In the proposed dB meter, we use an exponential waveform which does not depend upon the device parameters. The circuit for generating such a waveform is shown in Fig 1. The effect of temperature variations in RC values is eliminated by using a well-regulated reference source.

dB Meter

Let the decible (dB) value of a voltage V_i with respect to a reference voltage V_R be expressed as

$$\text{dB}\,\frac{V_i}{V_R} = 20\log_{10}\frac{V_i}{V_R}$$

The output voltage v_o of the circuit shown in Fig 1, when switch S (initially closed for a long time) is opened at $t = 0$, is given by

$$v_o = V\epsilon^{-t/RC} \tag{1}$$

Thus, at any time t_k voltage will be

$$V_k = V\epsilon^{-t_k/RC} \tag{2}$$

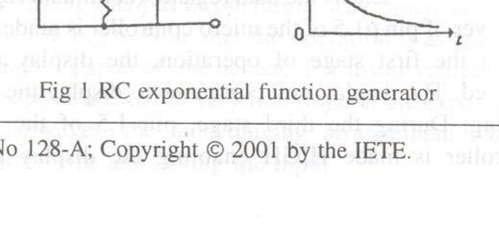

Fig 1 RC exponential function generator

If V_1 (V_2) be the value at time t_1(t_2), then from eqn (2), we get

$$\log_\epsilon \frac{V_1}{V_2} = \frac{1}{RC}(T_2 - T_1) \tag{3}$$

Multiplying both sides by $20\log_{10}\epsilon$, we get

$$20\log_{10}\frac{V_1}{V_2} = \frac{20\log_{10}\epsilon}{RC}(T_2 - T_1)$$

$$\text{dB}\,\frac{V_1}{V_2} = K(T_2 - T_1) \tag{4}$$

where $K = \dfrac{20\log_{10}\epsilon}{RC}$. Thus, dB value of V_1 with respect to voltage V_2 equals the product of K and the time difference $(T_2 - T_1)$. Based on the relation dB can be evaluated by using a micro-controller AT89C2051 as follows.

(1) Measure T_1 and store the value. The hardware circuit will be as shown in Fig 2. Close the switches S and S_1 and measure time difference T_1 from the instant S is opened and when the comparator output goes HIGH, i.e, when v_0 equals V_1. Repeat the same to measure T_2 with the help of switches S and S_2. The micro-control-

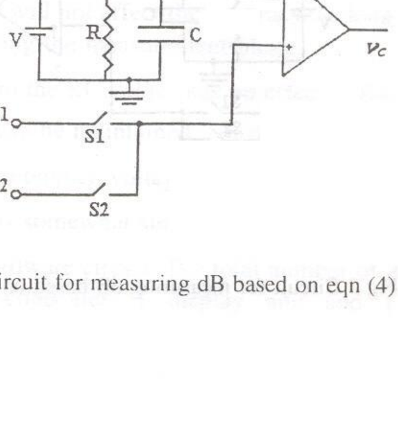

Fig 2 Circuit for measuring dB based on eqn (4)

ler has an in-built comparator. Hence, no external comparator will be required.

(2) Check if T_2 is greater or less than T_1. If T_2 is greater than T_1, the sign of the dB will be positive, otherwise negative.

(3) Then perform the mathematical operation as per eqn (4) through the software.

The drawback of the above method is that the dB value is dependent upon the RC value which will drift due to temperature variations, aging, etc and will produce error. This difficulty can be overcome as follows.

Similar to eqn (4), one can write

$$\mathrm{dB}\,\frac{V_2}{V_3} = K\,(T_3 - T_2) \qquad (5)$$

Substituting the value of K from eqn (5) into eqn (4), we get

$$\mathrm{dB}\,\frac{V_1}{V_2} = \mathrm{dB}\,\frac{V_2}{V_3}\left(\frac{T_2 - T_1}{T_3 - T_2}\right) \qquad (6)$$

Now based on eqn (6), dB measurement can be carried out using the circuit shown in Fig 3 as follows.

(1) Measure T_1 and store the value as explained above with the help of switches S and S_1. Repeat the same to measure T_2 (T_3) using the switches S and S_2 (S_3).

(2) Check if T_1 is greater or less than T_2.

(3) Perform the mathematical operation as per eqn (6) through the software.

Software can be simplified, if we choose

$$\mathrm{dB}\,\frac{V_2}{V_3} = 10^n \text{, } n \text{ is an integer} \qquad (7)$$

Thus, one has to calculate $\frac{T_2 - T_1}{T_3 - T_2}$ only and shift the decimal point in the display by n digits to the right. Let us choose $n = 1$, which requires $V_3 = 0.316V_2$. Higher values of n will result into V_3 considerably low. For example, when $n = 2$, $V_3 = 10^{-5}V_2$ which would be difficult to adjust

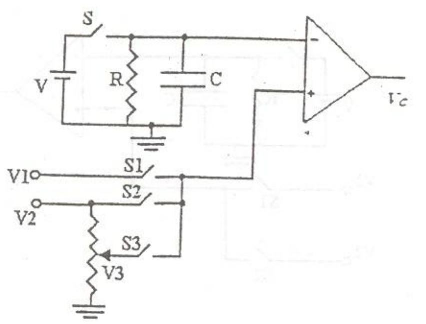

Fig 3 Circuit for measuring dB based on eqn (6)

accurately with the potentiometer (see Fig 3). Moreover, T_3 will not be measured accurately because of the very low slope of the exponential curve shown in Fig 1.

PRACTICAL SET UP

The hardware circuit was assembled as shown in Fig 4. We have used 20-pin DIP package micro-controller AT89C2051 [2] to accomplish the following operations through software.

(*i*) For operating the various switches

(*ii*) For measuring and storing T_1, T_2 and T_3

(*iii*) For calculating the dB value

(*iv*) For operating the display device.

The pin configuration of the controller can be seen in Fig 4. The unique feature of the controller is that it has an on-chip precision analog comparator. However, the comparator output is not accessible for outside use. Out of the total 20 pins, 15 pins (2, 3, 6-9, 11-19) are available for I/O use, pin 10 for ground, pin 20 for V_{DD}, and pin 1 for reset. However, if the internal comparator is used then pins 12 (NIN) and 13 (IN) (comparator input pins) cannot be used for I/O operation. Thus, effectively only 13 pins are available for I/O operation.

For display, ODM series LCD dot matrix module [3] is used. To operate this unit, 8 pins (7 to 14) to receive the data and 3 control pins (4, 5, 6) are to be connected to the micro-controller. Thus, the micro-controller will require 11 pins to transfer and control the data to the display unit. Further, 4 pins are required to operate the 4 switches. Thus, a total of 15 I/O pins will be needed, but we are left with only 13 pins at our disposal. The deficiency of 2 pins is managed (*a*) by permanently grounding the pin $\overline{W}/R$ of the display unit, (*b*) by connecting p1.6 to both the control pin of the switch, S and RS pin of the display unit. The operation of the dB meter with these connections is explained below.

Recall that the instrument works in three stages. In the first stage, capacitor C charges and then discharges. The values of T_1, T_2 and T_3 are stored. In the second stage, dB calculations are performed. In the third stage, the result is displayed.

Pin p1.6 of micro-controller has been connected to the control pin of the analog switch S and also to RS pin of the display unit. Thus, when p1.6 is HIGH (LOW), the switch S is closed (opened), the capacitor charges (discharges). At the same time, selects the data register (command register). However, if pin p1.5 of the micro controller is made LOW, during the first stage of operation, the display unit is disabled. The display unit continues to display the earlier reading. During the third stage, pin 1.5 of the micro-controller is made HIGH enabling the display unit to

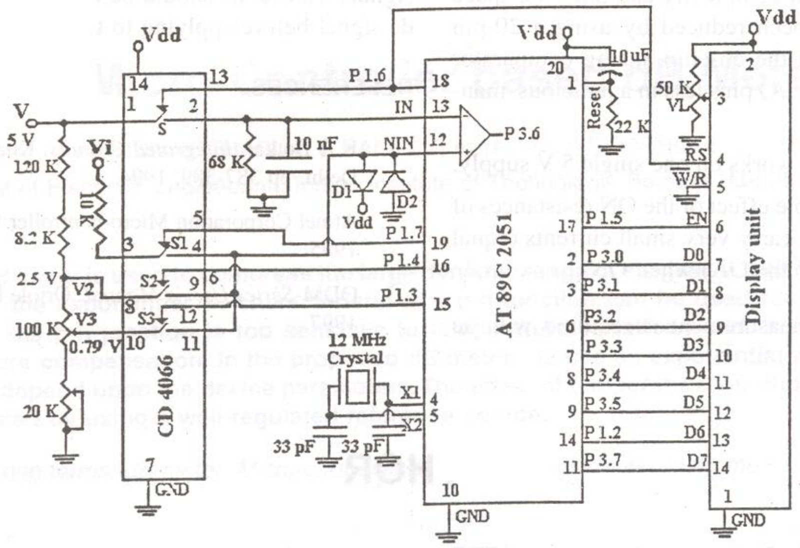

Fig 4 Practical set up for dB meter

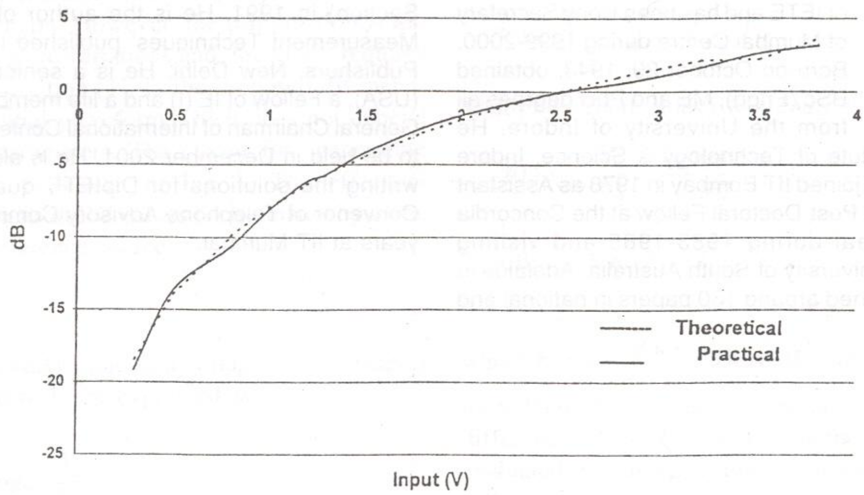

Fig 5 Comparison between theoretical and practical readings of dB meter

display the coming data. Note that pin $\overline{W}/R$ of the display unit is permanently grounded making it all the time LOW. Hence, data will continuously be taken in. In order to have the proper flow of the data, we have introduced an appropriate delay (of 4 ms) between two consecutive data transmissions. At this time the capacitor voltage is not accessed. Thus, the stages 1 and 3 do not interfere as far as working of the dB meter is concerned.

Diodes D_1 and D_2 are used to protect the comparator.

The circuit was put in operation. The practical results are shown in Fig 5. Note that the operation is as expected over roughly a span of one decade. For lower values, there is a large error due to the very low slope of the exponential curve. However, the auto-ranging arrangement can be incorporated for amplifying the input.

CONCLUSION

A simple micro-controller based dB-meter has been developed. It has the following advantages.

(1) Since the time differences $(T_2 - T_1)$ and $(T_3 - T_2)$ values in eqn (6) appear as ratio, the variation in clock frequency will not affect the accuracy, as long as it is stable during the measurement phase.

(2) The drift in the RC values has no effect. The factor dB $\frac{V_2}{V_3}$ can be maintained constant by using a well regulated reference voltage V_2.

(3) Software is somewhat simplified by choosing $n = 1$.

(4) Simple hardware circuit. The total number of ICs is 3 (1 micro-controller, 1 display unit and 1 quad

switches). The circuit complexity and thus, the space and the cost, have been reduced by using a 20-pin micro-controller and the on-chip analog comparator and managing with 2 I/O pins less in a judicious manner.

(5) The complete circuit works on one single 5 V supply.

(6) There is no appreciable effect of the ON resistances of the switches, as they carry very small currents (equal to the bias current of the OA) when ON.

In practice, the dB measurement is required with ac signals. Hence, ac should be converted into proportionate dc signal before applying to the circuit.

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AUTHOR

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