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 decibel (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

$$v_o = V_o = -\frac{1}{RC}$$

Thus, at any time $t$, voltage will be

$$V_t = V_e = -\frac{1}{RC}$$

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

$$\log_e \frac{V_1}{V_2} = \frac{1}{RC} (T_2 - T_1)$$

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

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

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

where $K = \frac{20 \log_{10} e}{RC}$. 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 $V_o$ equals $V_1$. Repeat the same to measure $T_2$ with the help of switches $S$ and $S_2$. The micro-control-
 ler has an in-built comparator. Hence, no external comparator will be required.

(2) Check if \( T_3 \) is greater or less than \( T_1 \). If \( T_3 \) 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

\[
\text{dB} \frac{V_2}{V_3} = K (T_3 - T_2) \tag{5}
\]

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

\[
\text{dB} \frac{V_1}{V_2} = \text{dB} \frac{V_2}{V_3} \left( \frac{T_2 - T_1}{T_3 - T_2} \right) \tag{6}
\]

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 \( S_1 \) (\( S_2 \)).

(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

\[
\text{dB} \frac{V_2}{V_3} = 10^n, \text{ } n \text{ is an integer} \tag{7}
\]

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 \( n = 2 \), \( V_3 = 10^{-3}V_2 \) which would be difficult to adjust 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 WR 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 microcontroller is made HIGH enabling the display unit to
display the coming data. Note that pin \( \overline{R/W} \) 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 \( \frac{V_3}{V_1} \) 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.

REFERENCES


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