

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/277593298>

A Simple and Inexpensive Implementation of Time Division Multiplier for two Quadrant Operation

Article in IETE Technical Review · March 2015

DOI: 10.1080/02564602.1995.11416496

CITATIONS

6

READS

107

2 authors, including:



[Jagadeesh Varadarajan Kumar](#)

Indian Institute of Technology Madras

155 PUBLICATIONS 1,919 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Performance enhancement of Pulse Oximeters [View project](#)



Design and Development of Floating Wiper Resistive and Inductive Displacement Sensors [View project](#)

A Simple and Inexpensive Implementation of Time Division Multiplier for two Quadrant Operation

C SELVAM, MIETE

Department of Mechanical Engineering, Indian Institute of Technology, Madras 600 036, India.

AND

V JAGADEESH KUMAR

Department of Electrical Engineering, Indian Institute of Technology, Madras 600 036, India.

The division multiplier technique proposed by Tomota, Sugiyama and Yamaguchi, is implemented in a simple way with minimum number of components. However the multiplier realised is of the two quadrant type.

IF the width (ON time) of a pulse train is made proportional to one voltage and the amplitude of the pulses to a second voltage, then the average value of the pulse waveform is proportional to the product of the two voltages, is very well illustrated by Tomato *et al* and others [1-3]. The circuit form that realises a multiplier employing the above principle is called the Time Division Multiplier (TDM). A simple implementation of the TDM is possible, if instead of a triangular wave form, a sawtooth wave is used as the reference clock. Such a circuit is described here.

CIRCUIT ANALYSIS

The simplified circuit is shown in Fig 1 and the associated waveforms are shown in Fig 2. The multiplier is made up of a

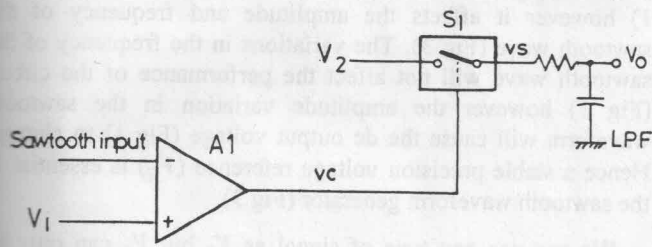


Fig 1 Simplified TDM

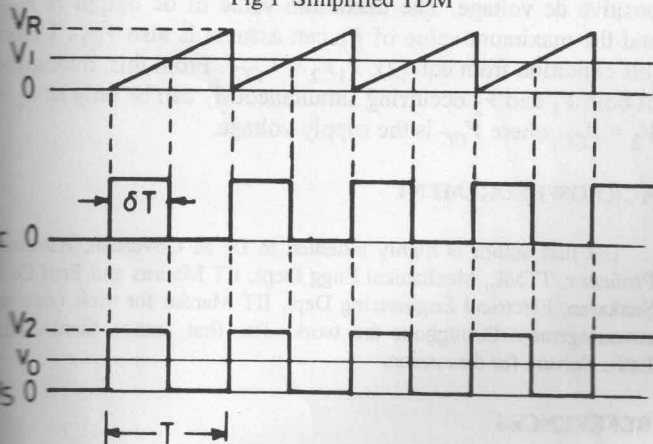


Fig 2 Waveforms of Fig 1

sawtooth generator, a comparator and a synchronous detector.

One of the input voltages V_1 is compared with sawtooth waveform V_i of period T and amplitude V_R by the comparator A_1 . A train of rectangular pulses V_c are produced with a time period of T at the output of the comparator. Its ON time δT will be

$$\delta T = \frac{V_1}{V_R} T \quad (1)$$

The analog switch S_1 samples the other input voltage V_2 during the ON time δT of V_c . At the output of the switch S_1 a pulse train V_s is produced with a time period of T , ON time of δT and amplitude of V_2 . The average voltage of V_s will then be

$$\begin{aligned} V_{\text{avg}} &= \frac{1}{T} \int_0^{\delta T} V_2 dt \\ &= \frac{V_2}{T} \delta T \\ &= \frac{V_1 V_2}{V_R} \end{aligned} \quad (2)$$

As shown in Fig 1, the RC low pass filter is used to get this average voltage. Its output V_o will be

$$V_o = \frac{V_1 V_2}{V_R} K \quad (3)$$

where K is the attenuation constant of the low pass filter.

GENERATION OF SAWTOOTH WAVEFORM

A sawtooth wave is generated by charging a capacitor at a specified rate and then rapidly discharging it with a switch. Figure 3 shows a circuit utilizing this principle [4]. A_2 is an integrator that forces the feedback capacitor C to charge a rate set by the input current I whose value is V_i / R . For proper operation, this current must always flow out of A_2 's summing junction; hence, V_i can take only negative values.

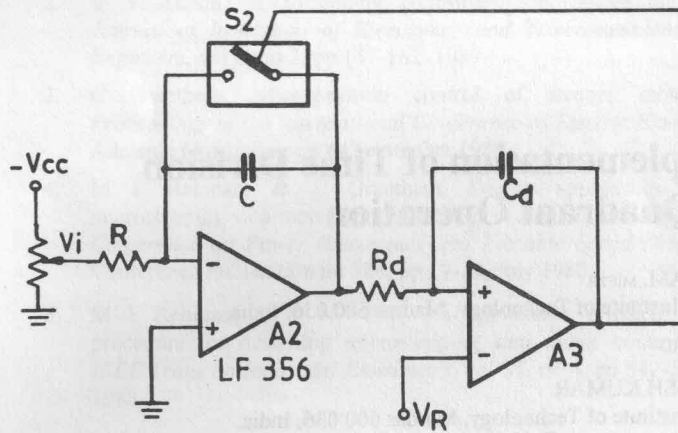


Fig 3 Generation of sawtooth waveform

During capacitor charge, the comparator output is at the LOW state and switch S_2 is in OFF state. The output of the integrator is given as

$$V_t = \frac{1}{RC} \int V_i dt = \frac{V_i}{RC} t \quad (4)$$

When the output of the integrator exceeds the reference voltage V_R , the comparator output is HIGH and the switch shorts the capacitor C, hence V_t comes down to 0 V.

The comparator is prevented from responding immediately to this change because of the charge accumulated in C during the comparator's output transition from 0V to +Vcc. This one-shot action, whose duration T_D is proportional to $R_d C_d$, is designed to ensure complete discharge of C by the switch. After timing out, the comparator output returns to LOW and the switch is opened allowing C to resume charging. The cycle, therefore, repeats itself at a period T. The waveforms thus generated are shown in Fig 4.

From the waveforms shown in Fig 4 and from the eqn (4), at time $t = T$, $V_t = V_R$

$$T = \frac{V_R RC}{V_i} \quad (5)$$

EXPERIMENTAL RESULTS AND CONCLUSION

The circuit shown in Fig 1 was realized with that of practical ICs as given in Fig 5 and tested in our Laboratory and the observations are shown in Table 1. LM 311 IC was used for the

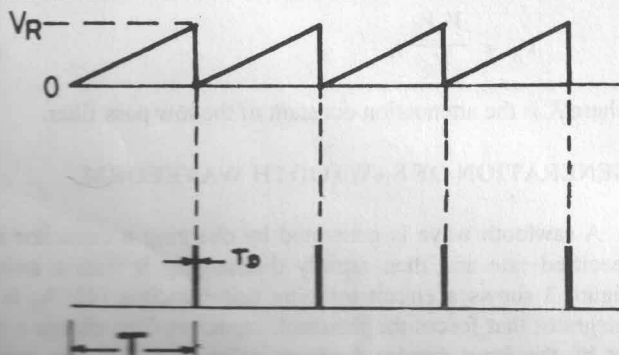


Fig 4 Waveforms of the Fig 3

comparator A_1 . The switch S_1 was realised with CD 4053 IC. The sawtooth waveform of time period 1 ms and amplitude V_R of 5V was generated by the circuit shown in Fig 3. LF 356 IC is used for A_2 , LM 311 IC is used for A_3 and switch S_2 can be realised with the second switch of CD 4053 IC employed for S_1 as the IC contains 3 switches.

TABLE 1 Experimental results

Input $V_1 = 1.2V$

Input V_2 (mV)	Experimental V_{out} (mV)	Calculated V_{out} (mV)	Constant $K = E/C$	Error %
1028	0222	0246	0.8999	-0.14
2028	0439	0486	0.9019	-0.07
3033	0656	0727	0.9012	0.00
4033	0873	0967	0.9019	-0.07
5066	1095	1215	0.9012	-0.00
			K average	0.9012

The accuracy of the circuit (Fig 5) strongly depends upon the sharpness and linearity of the sawtooth waveform. The offset voltage of all the op amps used may cause a little error in the output and hence must be adjusted to zero.

These circuits are used in power measurement to multiply two quantities which are proportional to voltage and current. As the ICs used are CMOS and LINEAR, the power supply variations pertaining to these ICs will hold good *ie* $\pm 10\%$ of the supply voltage $\pm 7.5V$ [5,6]. The small variations in the power supply will not affect the performance of the circuit (Fig 1) however it affects the amplitude and frequency of the sawtooth wave (Fig 3). The variations in the frequency of the sawtooth wave will not affect the performance of the circuit (Fig 1) however the amplitude variation in the sawtooth waveform will cause the dc output voltage (Fig 1) to change. Hence a stable precision voltage reference (V_R) is essential in the sawtooth waveform generator (Fig 3).

We can use any type of signal as V_2 but V_1 can only be positive dc voltage. The maximum value of dc output is V_{CC} and the maximum value of V_R can assume is also V_{CC} . Under this condition from eqn (2), $V_1 V_2 = V_{CC}^2$. From this, maximum of both V_1 and V_2 occurring simultaneously can be only at $V_1 = V_2 = V_{CC}$ where V_{CC} is the supply voltage.

ACKNOWLEDGEMENT

The first author is highly indebted to Dr M Govardan, Assistant Professor, TTML, Mechanical Engg Dept, IIT Madras and Prof Dr P Sankaran, Electrical Engineering Dept, IIT Madras for their constant encouragement throughout the work. The first author thanks Mrs Latha Selvam for discussion.

REFERENCES

1. M Tomata, T Sugiyama & K Yamaguchi, An electronic multiplier for accurate power measurements, *IEEE Trans on Measurement and Instrumentation*, vol IM, 17 no 4, Dec 1968.

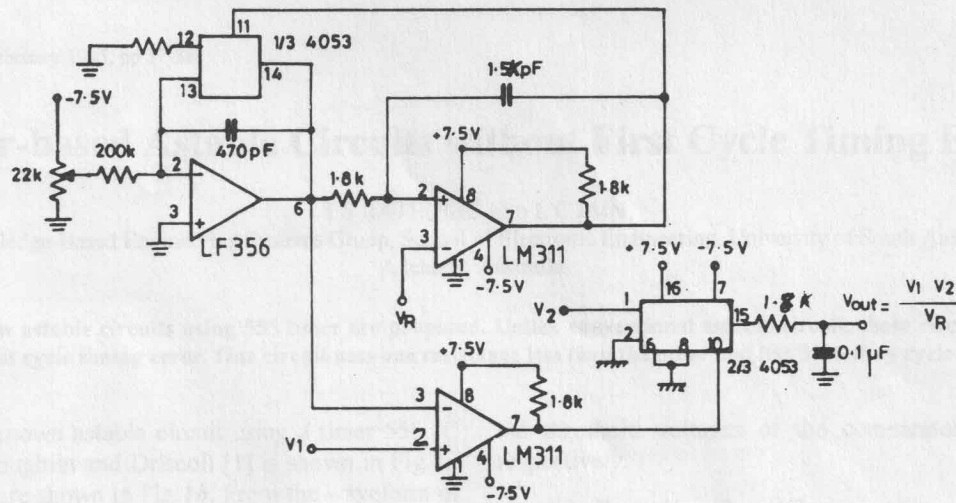


Fig 5 Complete circuit diagram of proposed TDM

2. C Selvam, A simple and low cost pulse time multiplier, *IETE Students' Journal*, vol 34, nos 3 & 4, pp 207-211, July-December 1993.

3. Yu Jen Wong & William E Ott, *Function Circuits: Design and applications*, McGraw Hill book Co, pp 91-93.

4. Sergio Franco, *Design with operational amplifiers and analog integrated circuits*, McGraw Hill book Co, pp 387-391.

5. CMOS data manual, National Semiconductor, 1982

6. LINEAR data manual, National Semiconductor, 1982.