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# Capacitance Meter with AT89C2051

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***Abstrak***

*Tidak semua multimeter mempunyai kemampuan untuk mengukur kapasitas kapasitor. Pada umumnya kemampuan ini hanya terdapat pada multimeter yang mahal harganya. Kapasitas suatu kapasitor dapat diperoleh dengan cara mengukur lebar pulsa yang dihasilkan oleh suatu multivibrator di mana kapasitor tersebut dihubungkan. Dengan mendayagunakan fungsi timer/counter yang terdapat pada mikrokontroler ATMEL 89C2051, lebar pulsa tersebut dapat diukur dan ditampilkan. Pada percobaan telah dapat diukur kapasitor antara 1nF hingga 470uF.*

***Kata kunci:*** *Pengukur kapasitor*, Multi-vibrator, on-chip timer/counter

**Abstract**

Measuring capacitor's capacitance sometimes cannot be done on simple multi-meter. These meters are not equipped with the capacitance meter function found on expensive multi-meter. With the advancing technology in IC integration, many micro-controller vendors have provided "on-chip timer/counter" (like ATMEL), that will cut cost on producing a simple capacitance meter. Capacitance is measured by pulse width that is constructed from a multi-vibrator. The ATMEL AT89C2051's "on- chip timer/counter" is used to measure, and calculated pulse width, then result is shown on a seven segments display. A simple prototype based on the AT89C2051 is able to measure capacitor ranging from 1nF to 470uF.

**Keywords:** Capacitance Meter, Multi-vibrator, on-chip timer/counter

## Introduction

Measuring capacitor's capacitance sometimes cannot be done on regular multi-meters. If it is possible, it usually is a very expensive meter. This paper tries to solve the problem by making a simple and low cost capacitance meter using a single chip ATMEL's micro-controller combined with National's multi-vibrator IC.

## Basic Theory

The capacity of a capacitor is found by charging it with a constant current rate and measured the time taken to arrive at a given terminal voltage. When it is applied to a multi-vibrator system, they produce pulse. A wider pulse produced by a multi-vibrator means larger capacitor's capacity.

The National's multi-vibrator IC, CD4047B, is capable to operate in either the mono-stable or a-stable mode. It requires an external capacitor (between pins 1 and 3) and an external resistor (between pins 2 and 3) to determine the output pulse width on mono-stable mode or the output frequency on a-stable mode [1].

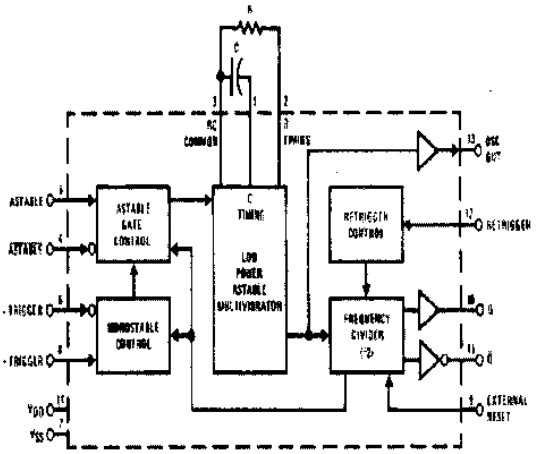

Figure 1. Block diagram CD4047B.

Table 1 below describes the multi-vibrator CD4047B's terminal connection to operate as a-stable mode and mono-stable mode.

Catatan : Diskusi untuk makalah ini diterima sebelum tanggal 1 Januari 2002. Diskusi yang layak muat akan dierbitkan pada Jurnal Teknik Elektro volume 2 nomor 1 Maret 2002

Table 1. Function table CD4047B.

| Function | Terminal Connections | | | Output Pulse | Typical Output |
|---|---|---|---|---|---|
| | To $V_{DD}$ | To $V_{SS}$ | Input Pulse To | From | Period or Pulse Width |
| Astable Multivibrator | | | | | |
| Free-Running | 4, 5, 6, 14 | 7, 8, 9, 12 | | 10, 11, 13 | $t_A$(10, 11) = 4.40 RC |
| True Gating | 4, 6, 14 | 7, 8, 9, 12 | 5 | 10, 11, 13 | $t_A$(13) = 2.20 RC |
| Complement Gating | 6, 14 | 5, 7, 8, 9, 12 | 4 | 10, 11, 13 | |
| Monostable Multivibrator | | | | | |
| Positive-Edge Trigger | 4, 14 | 5, 6, 7, 9, 12 | 8 | 10, 11 | |
| Negative-Edge Trigger | 4, 6, 14 | 5, 7, 9, 12 | 6 | 10, 11 | $t_A$(10, 11) = 2.48 RC |
| Retriggerable | 4, 14 | 5, 6, 7, 9 | 8, 12 | 10, 11 | |
| External Countdown (Note 1) | 14 | 5, 6, 7, 8, 9, 12 | Figure 1 | Figure 1 | Figure 1 |

Note 1: External resistor between terminals 3 and 2; external capacitor between terminals 1 and 2.

The ATMEL AT89C2051 IC is a low-voltage, high-performance 8-bits CMOS micro-controller with high-density non-volatile memory technology. It uses the industry-standard MCS-51 instruction set and provides: 2Kbytes of Flash, 128bytes of RAM, 15 I/O lines, two 16-bits timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a precision analog comparator, on-chip oscillator and clock circuitry [2].

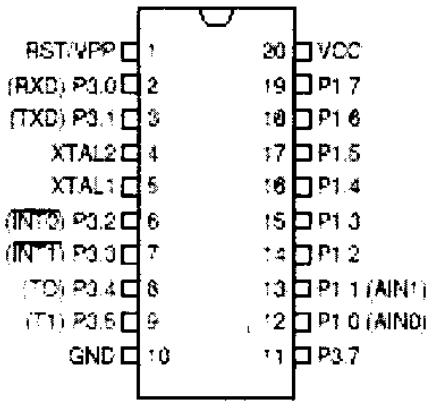


Figure 2. AT89C2051.

The two 16-bits timer/counter registers, Timer0 and Timer1, can be configured to operate either as Timers or Counters. Each has four operating modes: 13-bits timer, 16-bits timer, 8-bits auto reload, and split timers.

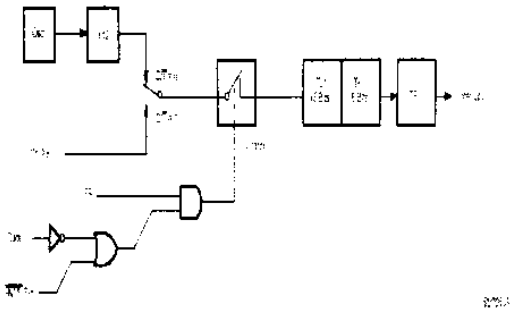

Figure 3. Mode-0: 13-bits counter.

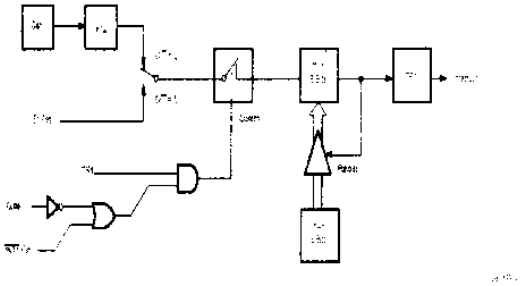

Figure 4. Mode-2: 8-bits Auto Reload.

AT89C2051's timer utility can used to quantify pulse width that is produced by the multi-vibrator (equivalent with capacitor's capacitance). Result from the micro-controller is shown at seven segments display.

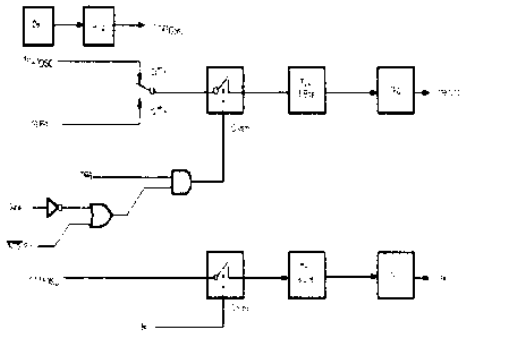

Figure 5. Mode-3: Two 8-bits counters.

**Experimental Results**

Table 2 below is based on experiment with prototype unit. CD4047B configured as a-stable free running mode and AT89C2051's Timer0 operated at mode-1 with a 12Mhz crystal. Timer0 at mode-1 counts up to 65535 counts in 65.535mS. With a 10K resistor, the prototype unit can calculate unknown capacitor's capacity using the formula T = 4.4 x R x C.

For example, 1nF capacitor provide 22uS high and low 22uS output period intermittently. Timer0 measures low periods, and then dividing it by 22 produces the capacitor value.

**Table 2.** Capacitor Measured

| Capacitor (nF) | Prototype (nF) | Reference (nF) |
|---|---|---|
| 1 | 1 | 1.12 |
| 3 | 3 | 3.11 |
| 5 | 5 | 5.09 |
| 11 | 11 | 11.11 |
| 16 | 16 | 16.11 |
| 20 | 19 | 19.91 |
| 35 | 34 | 35 |
| 51 | 50 | 51.1 |
| 76 | 75 | 75.95 |
| 100 | 98 | 100 |
| 150 | 147 | 149.8 |
| 200 | 196 | 199.2 |
| 500 | 490 | 501 |
| 700 | 687 | 703 |
| 1000 | 975 | 998 |

The experiment is based on Decade Capacitor Standard type DSC-1 from Ando Electric Co., LTD. Reference value are measured by 3½ digit Digital Inductance & Capacitance Meter model RE6000 (value Rp.700.000).

The prototype unit should not compare with the reference one; because of they precision are different. But with cost only below Rp.100.000 the prototype unit should be consider. For the other reason, a capacitor has a large tolerance. Therefore the prototype unit is a good choice for a low cost capacitance meter. Figure 6 illustrates the acceptable measurement accuracy of prototype unit compared to the RE6000.

The micro-controller AT89C2051 software can be upgraded by expanding its 16-bits Timer0 mode-1 to 24-bits using a free 8-bits internal register. Such prototype unit was tested well to measure a 470uF capacitor. If needed software can also be expanded to emulate 32-bits counter producing even higher capacitance measurement.

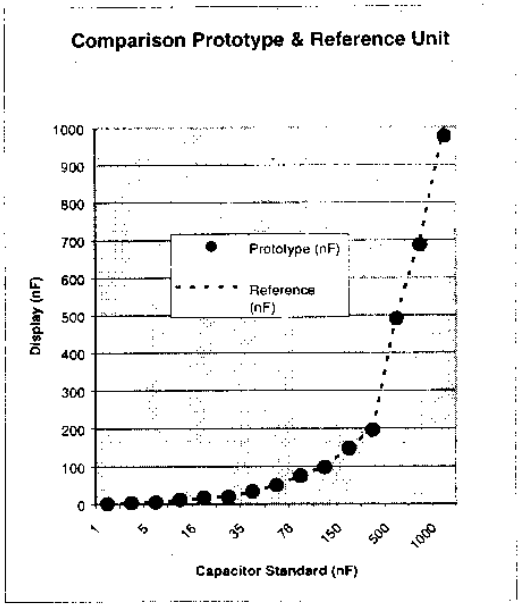


Figure 6. Comparison Prototype with Reference

Replacing the 12MHz crystal with a 24MHz crystal on the other hand, will make the prototype possible to measure capacitance under 1nF.

## Conclusions

This prototype unit is able to measure capacitor's capacitance from 1nF to 470uF, and still expandable by software applied; also able to measure capacitance smaller than 1nF on 24MHz crystal.

An auto range technique can be added to the software to provide easier measurement. Also with more seven segments display, this prototype unit will show more precisely value.

The prototype unit is a good choice for a simple and low cost capacitance meter.

## References

[1] _____, CMOS Logic Data Book, National Semiconductor Corporation, 1988.

[2] _____, Micro-controller Data Book, ATMEL Corporation, San Jose, 1995.