Application 8: Capacitance Meter

Purpose: This application shows how to use the PRIMER as a capacitance meter.

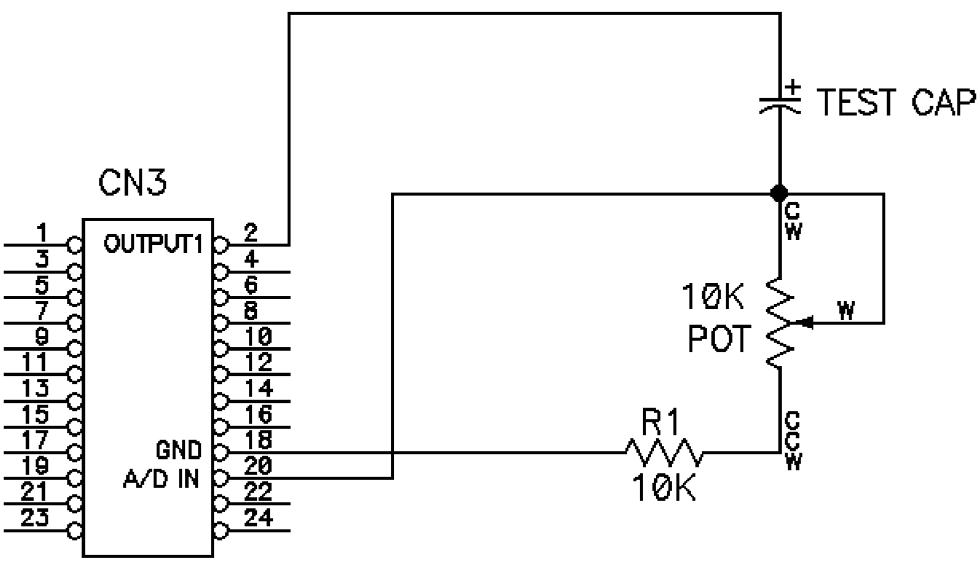
Discussion:

This application is an example of how the PRIMER can be used as a useful piece of electronic test equipment. The Capacitance Meter application can be used to accurately measure capacitors ranging from .01 to 220 uF.

The parts required are minimal. Items needed are:

1) 10K ohm mutiturn potentiometer
2) 10K ohm 1/4 watt resistor
3) one capacitor of a known value in the range of 1 to 100 uF (calibration cap)
4) several capacitors, for testing, in the range of .01uF to 300 uF
5) breadboard

The circuit is very simple. Follow the schematic below to assemble the circuit.



CIRCUIT DESCRIPTION

The PRIMER uses the on-board D/A converter, the comparator, OUTPUT1, and the timer within the 8155 to measure capacitance. The capacitor is connected in series with R1. The open end of the capacitor is then tied to OUTPUT1 and the open end of R1 is tied to ground. The D/A output of the PRIMER is tied to the non-inverting side if the op-amp comparator while the capacitor-R1 connection is tied to the inverting side. When the program first starts, the D/A is set slightly above ground potential and OUTPUT1 is set LOW. The capacitor now discharges through R1. The program waits for the comparator to go HIGH which indicates the capacitor voltage has fallen below the D/A voltage which guarantees a fully discharged cap. The program then starts the timer and sets OUTPUT1 HI which starts the capacitor charging. The timer is driven by a 307.2 Khz input Clock. The timer works by loading a “count” value into a register within the timer. The timer then decrements this value every time the input clock completes a cycle. When the value reaches 0, the timer generates an output pulse then reloads the register with the “count” value and the process starts all over again. By increasing the value in the “count” register the pulse rate can be slowed down and vise-versa. The Capacitor Meter program uses the timer as the time-base by counting how many pulses are generated by the timer while the capacitor is charging. The larger the cap, the longer the charge time, therefore the more pulses will be generated. The voltage across the resistor is near VCC when OUTPUT1 first goes HIGH, then ramps down as the capacitor charges. When the voltage falls below the D/A voltage the comparator output goes HIGH, stopping the timer. The current pulse count is then converted to decimal and displayed on the LED display.

CALIBRATION

The Capacitor Meter program works by measuring the time required to charge the capacitor through a resistor. The time-base is generated by the timer within the 8155. The Capacitor Meter program has 2 user selectable timer scales to choose from. The LO scale can measure capacitor values up to 9.999 uF while the HI scale can measure values up to 999.9 uF. Two scales were chosen to provide good resolution to small caps but also have the ability to measure large caps. The scale is determined by the “count” value loaded into the 8155 timer. A value of 10 is loaded in the “count” register for low scale and a value of 1000 for the high scale. Once the capacitor is charged the pulse count is displayed on the LED display in decimal. A decimal point is then placed on the LED display in the “10's” place for high scale and in the “1000's” place for low scale. So the actual value written to the display for a 1uF capacitor measured in low scale would be “1000". Once the decimal point is added it looks like “1.000". Because the Capacitor Meter uses a fixed time base to calculate capacitance, the resistor value must be determined to calibrate the Capacitor Meter.

The equation for capacitor charge time of an RC circuit is:

$$T = 5*R*C$$

Where:

T = Time in Seconds

R = Resistance in Ohms
C = Capacitance in Farads

Solving for R gives:

R = T/5C

The equation above is used to determine the approximate resistance value for the Capacitor Meter program.

Thus we can calculate the actual resistance value:

(1 / 307.2 Khz) * 10000 / 5 * 1uF = 6400 Ohms

This is the value for the total resistance. Keep in mind that the PRIMER has an in-circuit resistor with a value of 100 K ohms in parallel with the calibration resistor. The actual resistance value will be slightly above the theoretical value because the program does not charge the capacitor 100%. Other factors such as ESR (Equivalent Series Resistance) cause errors to grow quit large as capacitor values increase into the hundreds of uF's range. The value calculated is a good starting point but some final tweaking will be required.

USING THE PROGRAM

Following is the assembly language listing of the Capacitor Meter program:

```
;      CAPACITOR METER

P IN             EQU     12H      ;ADDRESS OF PORT A
P OUT            EQU     11H      ;ADDRESS OF PORT B
P 8155           EQU     10H      ;ADDRESS OF 8155 CONTROL REGISTER
P CNTLO          EQU     14H      ;ADDRESS OF LO BYTE OF COUNTER
P CNTHI          EQU     15H      ;ADDRESS OF HI BYTE OF COUNTER
TMRSTRT          EQU     0CDH     ;START TIMER COMMAND
TMRSTOP          EQU     8DH      ;STOP TIMER COMMAND
ADCVAL           EQU     01H      ;VALUE OF 1 TO D/A
TMRMODE          EQU     0C0H     ;SINGLE PULSE AND RELOAD
DSPORT           EQU     40H      ;ADDRESS OF LED DISPLAY DATA
DSPCMD           EQU     41H      ;ADDRESS OF LED DISPLAY COMMAND REGISTER
MOS              EQU     1000H    ;MOS SERVICE


      ORG     0FF01H              ;ORIGIN OF MEM IN 8155

START:
      MVI     E,ADCVAL            ;SET D/A TO LOW V
      MVI     C,0EH               ;SERVICE 0E (DACOUT)
      CALL    MOS                 ; MOS SERVICE

      MVI     A,TMRSTOP           ;STOP TIMER
      OUT     P 8155

      LXI     D,0000H             ;CLR D,E (PUT 0'S IN LED DISPLAY)
      MVI     C,13H               ;CALL LEDDEC ROUTINE IN MOS
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        CALL    MOS             ;

        MVI     A,80H           ;"WRITE COMMAND" FOR DIGIT 0
        OUT     DSPCMD

        MVI     A,00010111B     ;WRITE "F" TO DIGIT 0
        OUT     DSPORT

        MVI     A,81H           ;"WRITE COMMAND" FOR DIGIT 1
        OUT     DSPCMD

        MVI     A,11000001B     ;WRITE "u" TO DIGIT 1
        OUT     DSPORT

WAIT:
        IN    12H               ;GET SW0 SETTING
        ANI     01              ;MASK OFF OTHER SWCHS

        MVI     C,5             ;DECIMAL DIG 5
        MOV     B,A
        CALL    DECPNT          ;PLACES THE DECIMAL POINT
        XRI     00000001B       ;COMPLIMENT SW SETTING
        MOV     B,A
        MVI     C,3
        CALL    DECPNT
        MOV     B,A             ;SAVE SWITCH VAL

        MVI     C,16H           ;CALL SWITCH STAT
        CALL    MOS

        MOV     A,H
        RAR                     ;IF KEY WAS PRESSED,
        JNC     WAIT            ; THEN GO !

        MOV     A,B             ;IF DIPSWITCH1 IS ON
        RAR
        JNC     HI              ;THEN GOTO HI

LO:     MVI     A,0E8H          ;LOAD TIMER W/ 1000 D
        OUT     P CNTLO
        MVI     A,0C3H
        OUT     P CNTHI
        JMP     GO

HI:     MVI     A,0AH           ;LOAD TIMER W/ 10 D
        OUT     P CNTLO
        MVI     A,0C0H
        OUT     P CNTHI

GO:     XRA     A               ;CLEAR ACC
        OUT     11H             ;SET PORT A LO

POLE1:          RIM             ;POLE TO MAKE SURE CAP IS DISCHARGED
        RAL                     ;CHECK IF SID HAS GONE HIGH
        JNC     POLE1           ;IF NOT POLE

        MVI     A,0FFH          ;SET OUTPUT1 HIGH
        OUT     11H
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```
      MVI     A,TMRSTRT       ;START TIMER
      OUT     P 8155

LUP:  MVI     A,1FH           ;CLEAR 7.5 INT
      SIM                     ;SET INTERUPT MASK
POLE2:
      RIM                     ;LOAD ACC WITH INT FLG STATUS
      RAL                     ;CHECK IF SID HAS GONE HIGH
      JC      EXIT            ;IF SO THEN EXIT
      RAL                     ;CHECH IF 7.5 INT WENT SET
      JNC     POLE2           ;IF NOT THEN POLE
      INX     D               ;INCREMENT D AND E
      JMP     LUP             ;GOTO LUP

EXIT: MVI     C,13H           ;CALL LEDDEC ROUTINE IN MOS
      CALL    MOS

      MOV     A,B
      MVI     C,3
      CALL    DECPNT          ;PLACES THE DECIMAL POINT
      XRI     00000001B       ;COMPLIMENT SW SETTING
      MOV     B,A
      MVI     C,5
      CALL    DECPNT

STP:  MVI     C,16H           ;CALL KEYPAD STAT
      CALL    MOS

      MOV     A,H
      RAR                     ;IF A BUTTON WAS NOT PRESSED,
      JNC     STP             ;THEN POLE
      JMP     START           ;ELSE TEST ANOTHER CAP
;*****************************************************
; DECPNT:   IN: LOAD C W/ DIGIT #, LOAD B WITH A 1 OR 0
;                              B=1 DEC PNT ON, B=0 DEC PNT OFF
;           OUT: NOTHING
;-------------------------------------------------------
DECPNT:
      PUSH  PSW

      MOV   A,B
      RAL                     ;MOVE BIT 0 TO BIT 3 LOCATION
      RAL
      RAL
      ANI   00001000B
      MOV   B,A

      MVI   A,60H
      ADD   C                 ;COMMAND TO READ DIGIT
      OUT   DSPCMD

      IN    DSPORT            ;GET SEGMENT VALUES
      STA   TEMP              ;SAVE A REG

      MVI   A,80H             ;COMMAND TO WRITE DIGIT
      ADD   C
      OUT   DSPCMD
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```
       LDA   TEMP              ;RECALL A VALUE
       ANI   11110111B         ;TURN OFF DECIMAL POINT
       ORA   B                 ;TURN ON IF SUPOSED TO IS ON
       OUT   DSPORT            ;WRITE A TO DIGIT

       POP   PSW
       RET
TEMP   DS    1

       END
```

Load the following program into memory:

ADDRESS	DATA	INSTRUCTION	
FF01	1E	MVI	E,01
FF02	01		
FF03	0E	MVI	C,0E
FF04	0E		
FF05	CD	CALL	1000
FF06	00		
FF07	10		
FF08	3E	MVI	A,8D
FF09	8D		
FF0A	D3	OUT	10
FF0B	10		
FF0C	11	LXI	D,0000
FF0D	00		
FF0E	00		
FF0F	0E	MVI	C,13
FF10	13		
FF11	CD	CALL	1000
FF12	00		
FF13	10		

ADDRESS	DATA	INSTRUCTION	
FF14	3E	MVI	A,80
FF15	80		
FF16	D3	OUT	41
FF17	41		
FF18	3E	MVI	A,17
FF19	17		
FF1A	D3	OUT	40
FF1B	40		
FF1C	3E	MVI	A,81
FF1D	81		
FF1E	D3	OUT	41
FF1F	41		
FF20	3E	MVI	A,C1
FF21	C1		
FF22	D3	OUT	40
FF23	40		
FF24	DB	IN	12
FF25	12		

ADDRESS	DATA	INSTRUCTION	
FF26	E6	ANI	01
FF27	01		
FF28	0E	MVI	C,05
FF29	05		
FF2A	47	MOV	B,A
FF2B	CD	CALL	FF99
FF2C	99		
FF2D	FF		
FF2E	EE	XRI	01
FF2F	01		
FF30	47	MOV	B,A
FF31	0E	MVI	C,03
FF32	03		
FF33	CD	CALL	FF99
FF34	99		
FF35	FF		
FF36	47	MOV	B,A
FF37	0E	MVI	C,16
FF38	16		
FF39	CD	CALL	1000
FF3A	00		

FF3B	10		
FF3C	7C	MOV	A,H
FF3D	1F	RAR	
FF3E	D2	JNC	FF24
FF3F	24		
FF40	FF		
FF41	78	MOV	A,B
FF42	1F	RAR	
FF43	D2	JNC	FF51
FF44	51		
FF45	FF		
FF46	3E	MVI	A,E8
FF47	E8		
FF48	D3	OUT	14
FF49	14		
FF4A	3E	MVI	A,C3
FF4B	C3		
FF4C	D3	OUT	15
FF4D	15		
FF4E	C3	JMP	FF59
FF4F	59		
FF50	FF		
FF51	3E	MVI	A,0A
FF52	0A		
FF53	D3	OUT	14
FF54	14		
FF55	3E	MVI	A,C0
FF56	C0		
FF57	D3	OUT	15
FF58	15		
FF59	AF	XRA	A
FF5A	D3	OUT	11
FF5B	11		
FF5C	20	RIM	
FF5D	17	RAL	
FF5E	D2	JNC	FF5C
FF5F	5C		
FF60	FF		
FF61	3E	MVI	A,FF
FF62	FF		
ADDRESS	**DATA**	**INSTRUCTION**	
FF63	D3	OUT	11
FF64	11		
FF65	3E	MVI	A,CD
FF66	CD		
FF67	D3	OUT	10
FF68	10		
FF69	3E	MVI	A,1F
FF6A	1F		
FF6B	30	SIM	
FF6C	20	RIM	
FF6D	17	RAL	
FF6E	DA	JC	FF79
FF6F	79		
FF70	FF		
FF71	17	RAL	
FF72	D2	JNC	FF6C
FF73	6C		
FF74	FF		
FF75	13	INX	D
FF76	C3	JMP	FF69
FF77	69		
FF78	FF		
FF79	0E	MVI	C,13
FF7A	13		
FF7B	CD	CALL	1000
FF7C	00		
FF7D	10		
FF7E	78	MOV	A,B
FF7F	0E	MVI	C,03
FF80	03		
FF81	CD	CALL	FF99
FF82	99		
FF83	FF		
FF84	EE	XRI	01
FF85	01		
FF86	47	MOV	B,A
FF87	0E	MVI	C,05
FF88	05		
FF89	CD	CALL	FF99
FF8A	99		
FF8B	FF		
FF8C	0E	MVI	C,16
FF8D	16		
FF8E	CD	CALL	1000
FF8F	00		
FF90	10		
FF91	7C	MOV	A,H
FF92	1F	RAR	
FF93	D2	JNC	FF8C
FF94	8C		
FF95	FF		
FF96	C3	JMP	FF01
FF97	01		
FF98	FF		
FF99	F5	PUSH	PSW
FF9A	78	MOV	A,B
FF9B	17	RAL	
FF9C	17	RAL	
FF9D	17	RAL	
FF9E	E6	ANI	08
FF9F	08		
ADDRESS	**DATA**	**INSTRUCTION**	
FFA0	47	MOV	B,A
FFA1	3E	MVI	A,60
FFA2	60		
FFA3	81	ADD	C
FFA4	D3	OUT	41
FFA5	41		
FFA6	DB	IN	40
FFA7	40		
FFA8	32	STA	FFBA
FFA9	BA		
FFAA	FF		
FFAB	3E	MVI	A,80
FFAC	80		

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FFAD          81     ADD    C
FFAE          D3     OUT    41
FFAF          41
FFB0          3A     LDA    FFBA
FFB1          BA
FFB2          FF
FFB3          E6     ANI    F7
FFB4          F7
FFB5          B0     ORA    B
FFB6          D3     OUT    40
FFB7          40
FFB8          F1     POP    PSW
FFB9          C9     RET
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After loading the program, set the pot for midscale and install the calibration cap. Press FUNC. then RUN (to enter run mode). The display should read "0000 uF" with a decimal point in the "10's" place or in the "1000's" place. Change DIPSWITCH 0 to change the decimal point position. With the decimal point in the “10's” place, the Capacitor Meter program can measure capacitor values up to 999.9 uF. With the decimal point in the “1000's” place, values up to 9.999 uF can be measured. Once the scale is chosen, press any key on the keypad to test the cap. A value will be returned to the display which represents capacitance. Press another key to start the program over again. Adjust the pot and continue to test the calibration capacitor until an accurate reading is realized. Test several caps and record the results. Accuracies greater than 99% are possible.

NOTE- The most accurate results will be obtained when the PRIMER is powered up and the temperature allowed to stabilize over a period of 15 to 30 minutes.