CALCULATOR CHIP MAKES A COUNTER

INTRODUCTION

In applications that require counting at fairly low rates and display of the accumulated total, the MM5736 calculator chip can be used to yield a very low parts count solution. Such applications include: timers, stop-watches, bin counters, digital panel meters, coordinate counters and nearly all applications that currently use mechanical counters. A 6 digit counter that will drive a LED display and count at a maximum rate of about 60 Hz can be constructed with only 2 integrated circuits. Higher counting rates, simplified control, and more versatile display driving capability can be obtained with the addition of a few more components. Counting is accomplished by loading a "1" into the calculator and causing an "add" each time the counter is incremented. But before describing any actual counters, a brief explanation of the calculator's operation is in order.

GENERAL DESCRIPTION

The MM5736 is a 6 digit, no decimal point, five function calculator. These five functions are: ADD, SUBTRACT, MULTIPLY, DIVIDE, and CLEAR. The calculator has 3 inputs (K_1, K_2, K_3) that are designed to be driven by a keyboard matrix and two sets of outputs: 6 "digit" outputs and 7 "segment" outputs. The segment outputs provide a positive true, 7 segment code that represents the information in the calculator's display register. These outputs are multiplexed such that the 7 segment code for digit 1 appears on the segment outputs during digit time 1. The code for digit 2 appears during digit time 2 and so on as illustrated in *Figure 1.* These outputs are designed to drive a LED readout in a "digit" multiplexed manner by strobing the LED characters with the digit outputs. The digit outputs can not drive the LED display directly and must be buffered

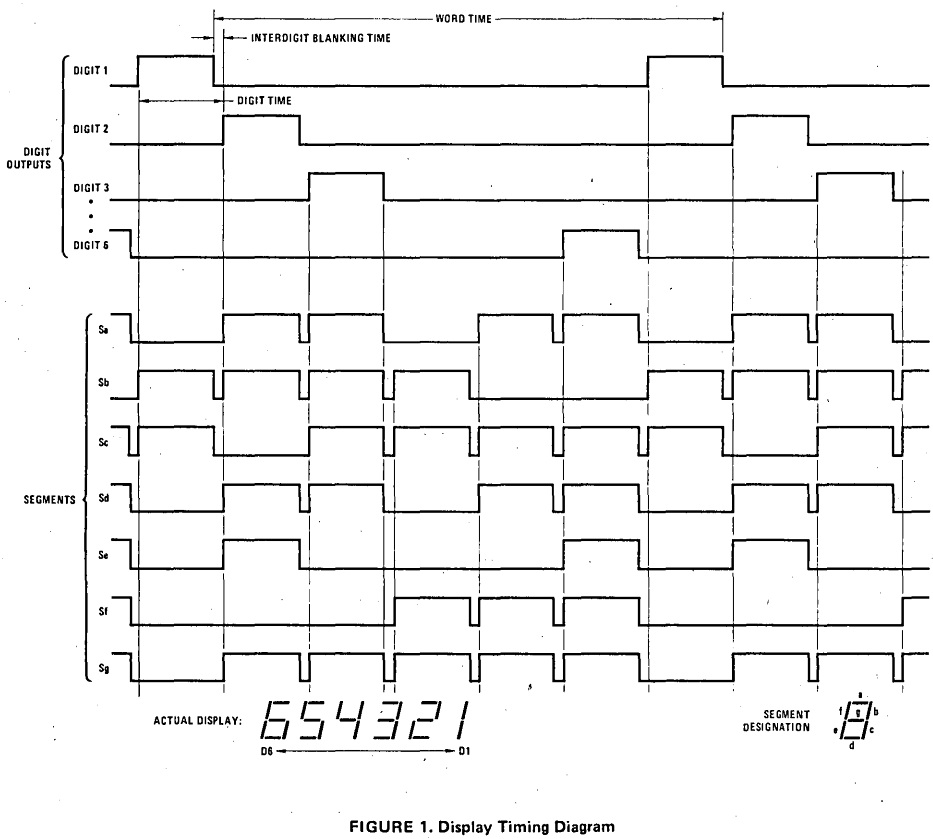

FIGURE 1. Display Timing Diagram

with a DM75492 digit driver. The segment outputs will drive some LED displays directly but the designer must choose the display carefully if he does not wish to use segment drivers. National's line of low current LED displays, such as the NSN66A and NSN98A, can be driven directly by the calculator chip.

ENTRY INTO THE CALCULATOR

Numbers are entered into the calculator by connecting the appropriate digit output to either the K_1 or K_2 input. Arithmetic operations (and the clear operation) are initiated by connecting the appropriate digit output to the K_3 input. Table I shows the combinations of digit outputs and K inputs.

TABLE I.

Digit #	K_1	K_2	K_3
1	0		CLR
2	1	6	
3	2	7	–
4	3	8	+
5	4	9	X
6	5		÷

Note: Blanks are illegal connections.

Switch debounce is done in the calculator chip and is accomplished by requiring that the digit output of interest be connected to the proper input for at least 8 consecutive word times (see *Figure 1*). Before another entry can be made, at least 8 word times must elapse during which none of the digits outputs are applied to the K inputs. This requirement limits the speed of the calculator but is necessary to provide an adequate debounce timeout. A method of speeding up this timeout is discussed later.

POWER REQUIREMENTS

The MM5736 will operate from a single supply voltage anywhere between 6.5V and 9.5V. The calculator chip itself will draw about 6 mA. If a LED display is driven directly, without segment drivers, the current that drives the display must come through the calculator so the total power supply current could be as high as 110 mA but will typically be about 50 mA. This is dependent to some extent on the supply voltage and the nature of the particular digit drivers that are used.

NO POWER SUPPLY RAMP ALLOWED

The power supply voltage must come up to an operational level fairly quickly since a slow ramp will not always initialize the calculator properly. The chip was designed for battery operation where the dc source is switched. If the chip is used in a system with a heavily filtered power supply, some provision should be made to allow the V_{SS} terminal of the calculator to rise abruptly. After power up, the calculator should be cleared twice to ensure that all registers are reset to zero. The first CLEAR operation affects only the display register, the second CLEAR affects all other registers.

CMOS COMPATIBILITY

The MM5736 is directly compatible with Nationals' 74C line of CMOS. The number of CMOS loads the calculator can drive is limited only by degradation in waveshape due to capacitive loading. Loads of 200 pF or less should present no problem to the digit outputs but the segment outputs should not be loaded with more than about 50 pF. This means fanout should be limited to about 10 on the digit outputs and 4 on the segment outputs. The CMOS can be run from the same supply as the calculator and still drive the calculator inputs directly. This compatibility makes interfacing with the calculator a breeze.

SIMPLEST COUNTER

Figure 2 shows a 6 decade counter that drives a display and requires a minimum of parts. This circuit's maximum counting rate will typically be about 60 Hz. Some chips may run as slow as about 40 Hz while some may run as fast as 150 Hz due to inherent variations of the on-chip oscillator from calculator to calculator. This counter is useful in applications where speed is not

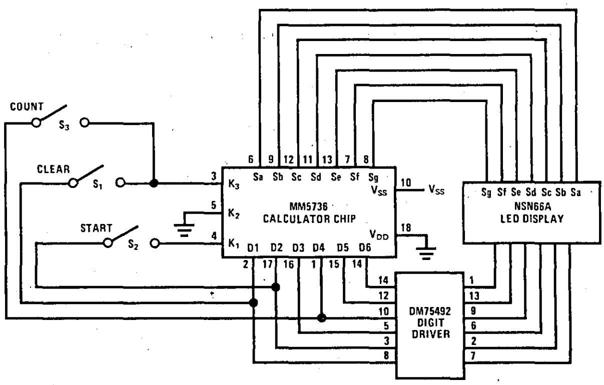

FIGURE 2. Simplest Counter

an important factor and where the counter is reset manually. The resetting of this circuit consists of two operations, clearing the calculator and entering a 1 into it again (only one CLEAR operation is needed following an arithmetic operation). The circuit in *Figure 2* leaves these two operations to the operator; he must first clear the counter by depressing S_1 to the CLEAR position and then he must enter a 1 into the machine by depressing S_2 to the START position. This allows the operator to control when the counting starts without gating the "count" input.

In case the impact of this escaped you, let's repeat it: the circuit in *Figure 2* demonstrates a 6 decade counter and everything that is needed to drive a 6 digit LED display, yet this circuit requires only two integrated circuits!

Figure 3 indicates how to build this same counter using segment drivers. The DM8895 segment driver can be mask programmed to source several values of current. Since the values of current that are readily available will change from time to time, National should be consulted about the DM8895 before a design using it is undertaken. The general range of currents available is from 5.0 mA up to about 17 mA per segment. This means that fairly large displays can be used. Noteworthy is the fact that the current that drives the display in this configuration is not supplied by the calculator chip. Instead, this current comes from the V_{CC} supply terminal of the DM8895. The DM8895 will continue to operate as long as the voltage between the V_{CC} terminal and each output is at least 1.6V. This means V_{CC} can be operated at a lower level than V_{SS}, resulting in a power saving. The voltage on an output of the DM8895 when the segment is ON is determined by the saturation voltage of the digit driver (typically 1.0V for the DM75492) and the voltage across the LED (typically about 1.8V). Consequentially the typical minimum value of V_{CC} is about 4.4V. Worst case conditions will result in a minimum V_{CC} of about 5.3V.

Figure 4 again indicates how to build this same counter but this time using different segment drivers. In this circuit, the current drive to the LED's is determined by the external current limiting resistors. Here again the current to the display is supplied by V_{CC} which can be less than V_{SS}, again resulting in a power saving and the ability to drive large LED displays.

SELF STARTING COUNTER

With the addition of only one package of CMOS gates, a counter can be built that does not require a separate "start" operation to enter an initial 1 into the calculator chip. This circuit is shown in *Figure 5*. When the RESET switch is returned to its normal position after clearing the calculator, the additional parts generate a delayed pulse that gates digit output 2 into the calculator and thus enters a 1. This allows the counter to be reset in a single operation.

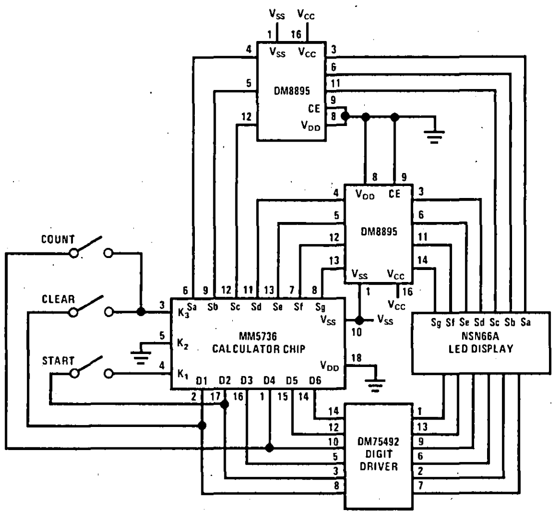

FIGURE 3. Counter with Segment Drivers

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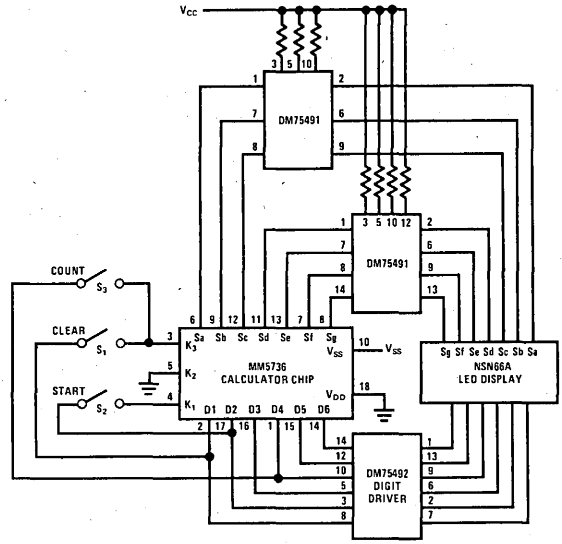

FIGURE 4. Counter with Segment Drivers and External Current Limiting Resistors

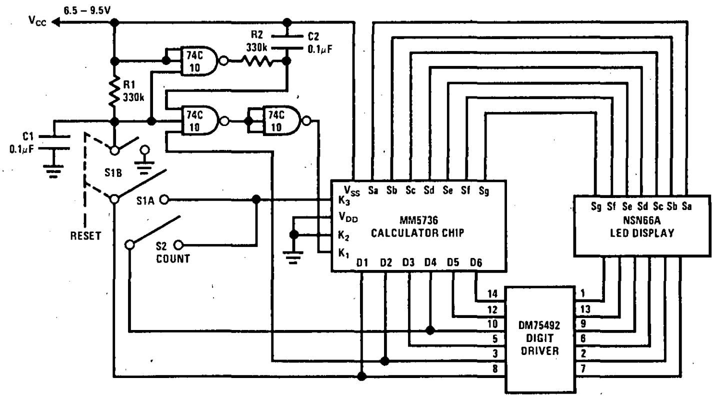

FIGURE 5. Counter with a Single Clear Switch

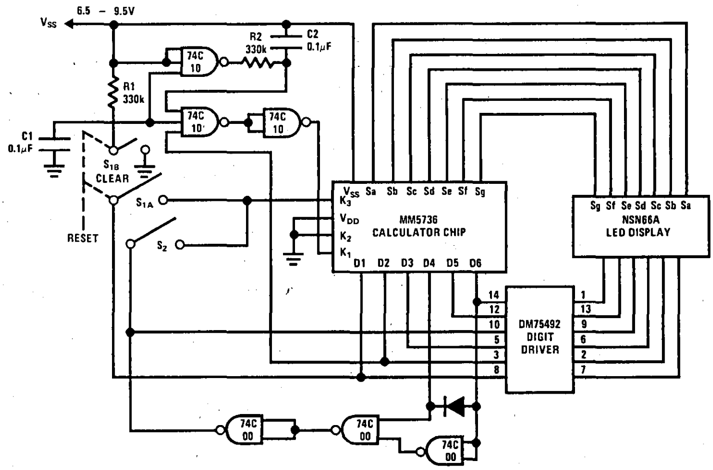

FIGURE 6. Counter with Increased Speed

FASTER COUNTING RATES

Figure 6 illustrates how to speed up the circuit shown in *Figure 5* so that it will count at a higher rate. The actual maximum counting rate attainable with this circuit will depend on the particular MM5736 used but will run from about 80 Hz up to about 300 Hz. A reasonably typical speed is about 120 Hz. This circuit could also be used with segment drivers as previously described. The increase in counting rate is obtained by feeding digit output 6 back to the digit 4 output thereby fooling some internal logic. However this results in a double pulse on the digit 4 output which must be gated back to a single pulse at the normal digit 4 time. This requires one diode and one additional package of CMOS gates. In reality, very few relays or switches will operate at these speeds. Consequently, applications requiring these higher counting rates may have a normal logic signal to count rather than relay closures. *Figure 8* illustrates this. In this configuration the input must be high at least 4 word times and the duty cycle cannot exceed 50%. A word time will vary from 420μs to 1.6 ms with 1.0 ms being typical.

MORE VERSATILITY

These counters can be made to count by numbers other than 1 by causing the desired number to be entered into the calculator during the START operation. Table I indicates which connections must be made. The counters can also be made to count down by doing successive subtractions rather than successive additions. Both could be used to build an up/down counter, the only restriction being that trying to count up and down at the same time is no fair. *Figure 7* shows a circuit that counts up and down by 4's. Such a counter might be used to keep track of inventory in a bin. In this case, the parts to be inventoried are packaged in groups of 4. When a package is put into the bin, switch S_2 is activated and the counter adds 4 to the accumulated total. When a package is taken out of the bin, switch S_3 is activated and the counter subtracts 4 from the accumulated total.

RETAINING FULL USE OF THE CALCULATOR

Counters can be built such that full use of the calculator is retained. This requires that the usual keyboard arrangement of the calculator be undisturbed by the counting logic. *Figure 8* illustrates a circuit that uses MOS transistors to accomplish this. In this circuit, normal calculator operation is retained when S_2 is in the "calculate" position since all four MOS transistors (Q1–Q4) are "off" (gates are at V_{CC}) and the circuit is essentially the same as the "recommended calculator" circuit in the MM5736 data sheet. If the "RESET" switch is activated D1 is connected to K_3 and the calculator is cleared. Capacitors C1 and C2 are discharged while S_1 is activated but as soon as S_1 is released C1 and C2 will charge up generating a delayed pulse (negative going) on the gate of Q2 which gates D2 into K_1 and causes a 1 to be entered into the calculator. The delay caused by C1 is necessary to allow the CLEAR function to be debounced by the calculator chip as mentioned earlier. When S_2 is in the "COUNT" mode Q4 is turned on and D6 is tied to D4. This doubles the maximum counting rate by reducing the internal debounce timeout. The count input is now enabled and an input pulse will turn Q1 on. This gates D4 into the K_3 input and causes the calculator to perform an addition. Each subsequent input pulse causes 1 to be added to the sum. When S_2 is returned to the "calculate" position the count input is disabled and Q4 is turned off returning the keyboard logic to its normal state. This same circuit can be implemented with MM74C02 NOR gates instead of MM74C00 NAND gates. The MOS transistors can then be replaced with an MM5616 CMOS switch.

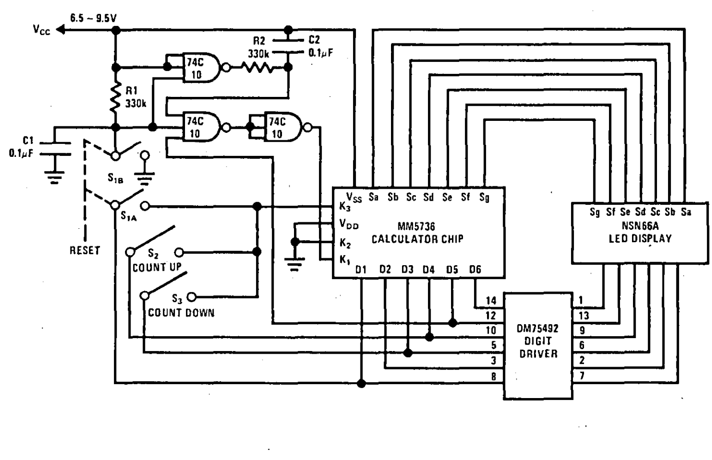

FIGURE 7. Up-Down Counter

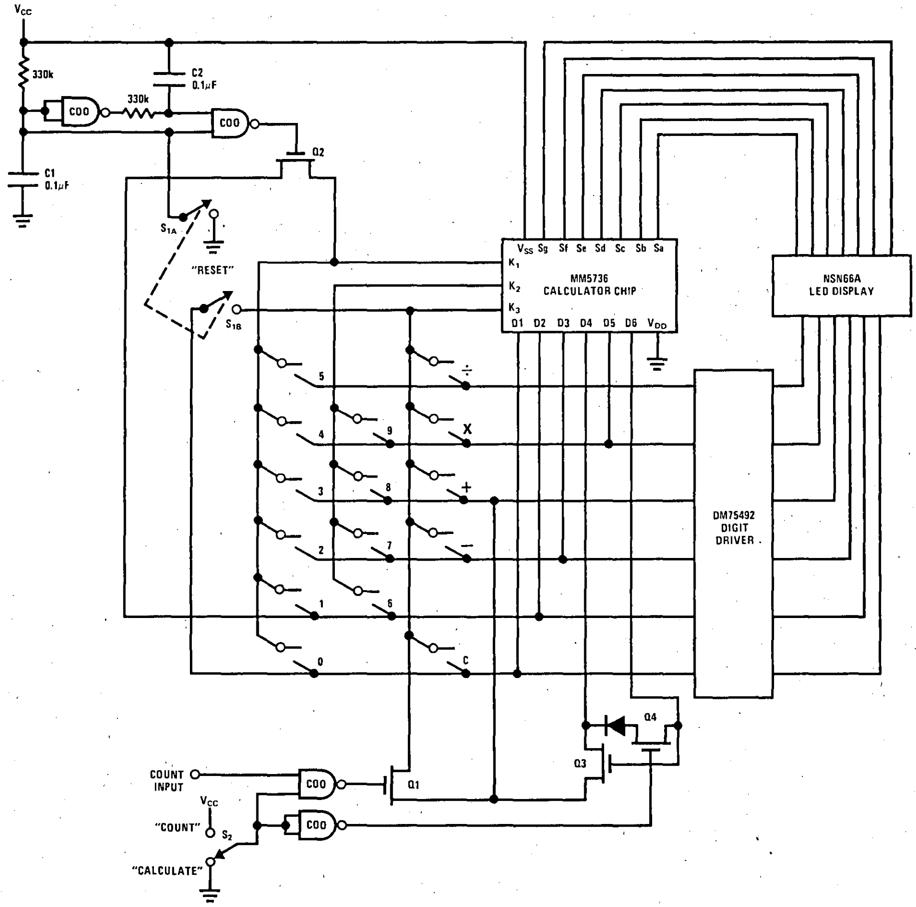

FIGURE 8. Calculator/Counter

SUMMARY

Many versatile counters can be built using the MM5736 or its 9-digit equivalent, the MM5739, calculator chips. These counters should yield very cost effective solutions to a variety of counting applications. The major disadvantage of these counters is that they are relatively slow. The major advantages these counters offer are:

1. The ability to directly drive a LED display.
2. The ability to debounce switch or relay inputs.
3. 6 decades of counting in one DIP.
4. Low cost.
5. Low parts count.