SIEMENS

Multiplexing LED Displays
Appnote 3

by George Smith

In digital displays, such as would be used in a D.V.M. or counter of conventional design, all digits are operated in parallel, with a separate decoder-driver for each digit operated from data generally stored in a quad latch.

In many cases, a reduction in cost can be effected by operating the display in a time division multiplexed mode. The question of cost effectiveness depends on the particular application. As a general rule, the greater the number of digits in the display, the more advantageous the multiplex system becomes from the cost standpoint. Because of the great variety of situations possible, it is difficult to say at what number of digits the change should be made. In some circumstances, non-multiplexed operation of less than 8 digits is more economical. On the other hand, there are circumstances where multiplexing is used for three and four digit displays at a cost saving. This application note attempts to show some of the many ways of multiplexing digits. The designer can decide whether his/her own system application would be lower in cost by using a multiplex scheme.

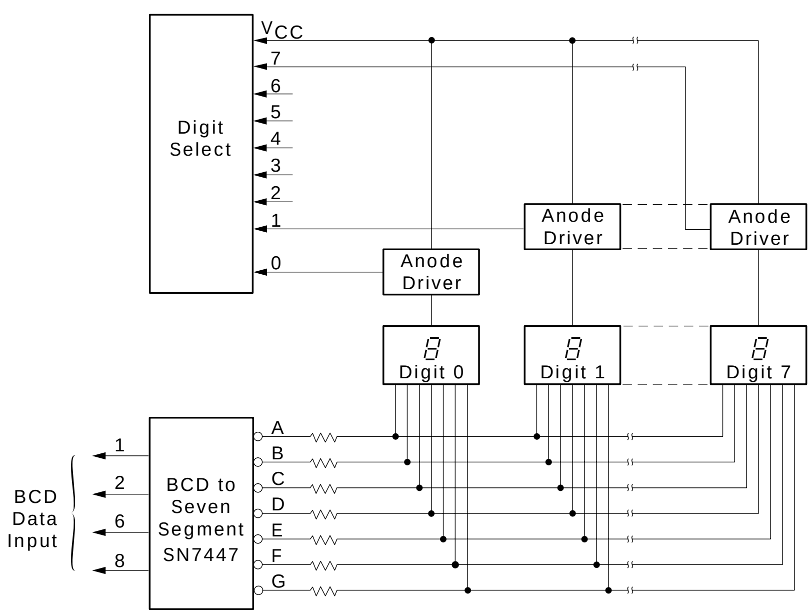
The properties of light emitting diodes (LED) make them particulary suitable for multiplexed operation, and hence it is the preferred method to use, if a scheme can be designed which is cost competitive with non-multiplexed operation.

It will be generally assumed that we are talking of a system using TTL type logic families, with MSI functions being used where applicable. In most production situations this will be the most economical approach. There will be some cases where discrete gates and flip-flops may yield a lower cost. There are also cases where a single MOS chip contains all the necessary logic functions and only interface driver circuits are required.

The seven segment numeric displays with a common anode connection made by Siemens provide compatibility with the most widely available decoder-drivers, which are active level low outputs. The commonest device is SN7447 or similar. Any of these is suitable for driving displays: HD107XX, HD110XX or HD1131XX series. For common cathode displays, such as the Siemens DL330M, DL340M, DL430M, or DL440M, a SN7448 decoder can be used, and anode drivers become cathode drivers.

In a multiplex system, the corresponding cathodes of each digit are bussed together and driven from one seven segment decoder-driver via the usual current limiting resistors. The display data is presented serially by digit to the decoder-driver, together with an enable signal to the appropriate digit anode (Figure 1).

Figure 1.



Each digit anode is driven by a switch, capable of passing the full current of all segments. The simplest switch would be a PNP high current switch or amplifier transistor, such as a core driver type.

In operation, the anode switches are activated one at a time, in the desired sequence, while the appropriate digital data is presented at the input to the decoder driver. The amount of circuitry required in Figure 1 is much less than that used in the non-multiplexed scheme. The question of overall economy depends on the amount of circuitry required to sequence the anodes and present the data at the decoder input. Let us consider some typical situations.

Case 1

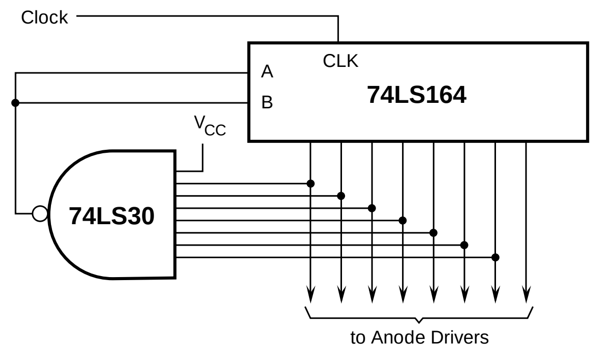
An 8-digit counter-timer display with the data stored in multiple latch circuits is the most common situation present in a counter-timer of conventional design. A quad latch (SN7475) is used to store each digit, and this data is periodically updated. To scan this data, a 4 pole 8 position switch is required (SN74151). To select the appropriate digit, an octal counter (SN7493) and a BCD decoder (SN7442) are required. The complete circuit is shown in Figure 2.

The total package count is about half the same for this arrangement, as for non-multiplexed operation, but most of the packages are lower cost than the seven segment decoder. The scheme shown is a 20% cost reduction over non-multiplexed operation, based on O.E.M. prices for the components. For less than eight digits, it would be difficult to compete with non-multiplexed operation using this scheme.

Case 2

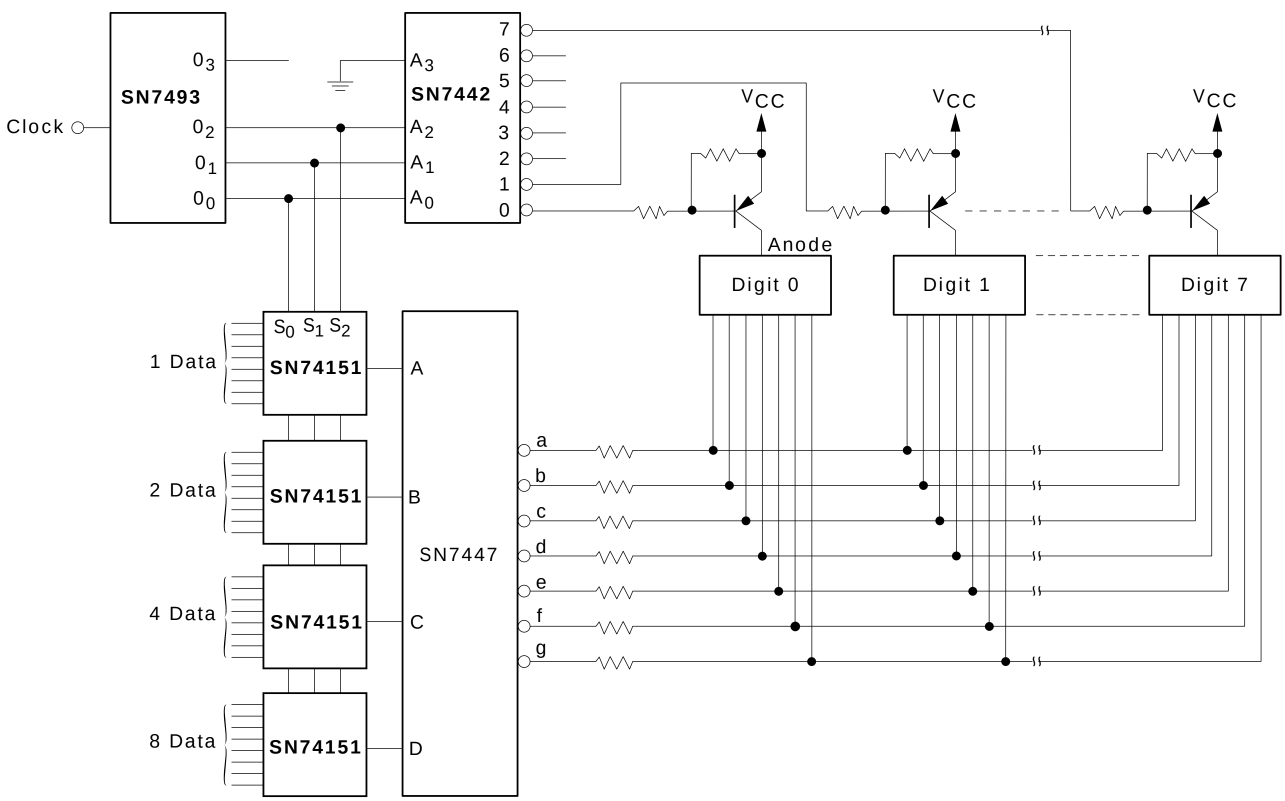
Multiplexing becomes more attractive when the data is stored in a shift register, rather than in latches. In this case the data is circulated around the register at some suitable rate and is sequentially presented at the input of the seven-segment decoder-driver. The anode drive can be obtained from a counter and decoder as in Figure 2, or from a parallel output shift register, Figure 3.

Figure 3.



This circuit, which can be expanded to any number of digits, circulates a single zero, and can directly drive the PNP anode switches. Systems using recirculating memories generally require this digit timing circuitry for other reasons, so it is generally already available in the system.

Figure 2.



For displays of eight digits; a very common number in counter-timer instruments, the 741648 bit shift register makes a very good circulating shift register.

The scheme can be extended to more digits by adding a four bit shift register, such as the 7494; the extra shift bits are inserted at the points marked ⓧ in Figure 4. The same circuit can be used for less than eight digits, if a 12½% duty cycle is satisfactory.

The preceding schemes demonstrate that systems containing recirculating data are very effectively coupled to multiplexed LED displays. Many multi-digit systems such as calculating machines use L.S.I. MOS circuits to provide their logic, and these naturally lend themselves to recirculating data. It is now practical to use microprocessors in instruments, which work well with Siemens Intelligent Display devices.

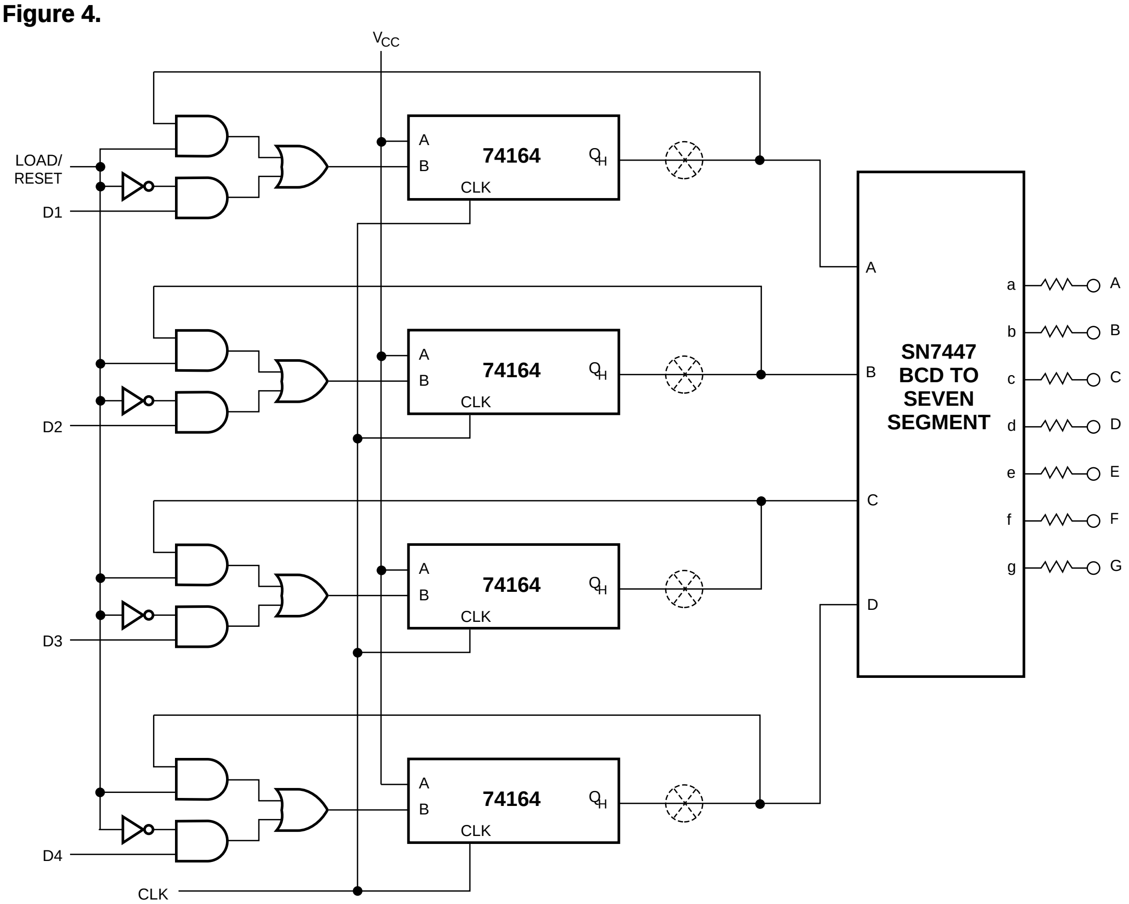
Apart from the strictly logical problems involved in a multiplexed display, the designer must choose suitable operating conditions for the LEDs. Peak forward current, current pulse width, duty cycle and repetition rate are all factors which the designer must determine.

The luminous intensity, or the luminance of GaAsP LEDs, is essentially proportional to forward current over a wide range, but certain phenomena modify this condition. At low currents, the presence of nonradiative recombination processes results in less light output than the linear relationship would predict. This effect is noticeable just below 5 mA per segment (for ¼ inch characters). The result is that noticeable difference in luminance from segment to segment can occur at low currents. At high currents, the power dissipation in the chip causes substantial temperature rise, and this reduces the dissipation efficiency of the chip. As a result, the light output versus forward current curve falls below the straight line, at high currents (Figure 5). It should be emphasized that this latter effect is entirely due to self heating. If the power dissipation is limited, by running short pulses at low duty cycle, the output follows the straight line up to very high current densities. Whereas 100 A/cm^2 may be used in DC operation, as much as 10^4 A/cm^2 can be used under pulsed conditions, with a proportionate increase in peak intensity. (If this did not occur, GaAsP lasers could not be built.) Gallium Phosphide, however, has an inherent saturation mechanism that causes a drastic reduction in efficiency at high current densities even if the junction temperature remains constant. This effect is due to competing non-radiative recombination mechanisms at high current density.

As a first approximation the brightness of a pulsed LED will be similar to being operated at a DC forward current equal to the average pulsed current. For example, for 40 mA peak current at 25% duty cycle, the brightness will be similar to DC operation at 10 mA. The actual brightness comparison will depend on the actual pulsing conditions. Under most legitimate conditions the brightness will be greater for pulsed operation.

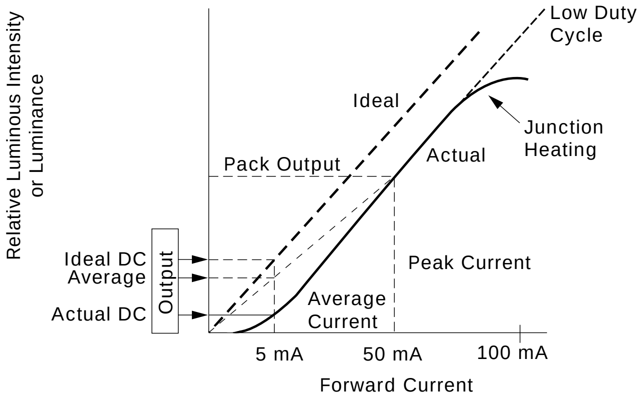
Figure 5 shows how the actual light output at 5 mA DC is substantially less than expected from the ideal curve, because of the “foot” on the curve at low currents. Operation at 50 mA peak current and 10% duty cycle yields a high peak output as shown, and an integrated average output that is much closer to the ideal value. It should be obvious that variations in the “foot” from segment to segment cause a significant variation in light output at a low DC current, but a much smaller variation in the average output when operated in a pulsed mode. As well

Figure 4.



as an increase in luminance, or luminous intensity due to pulsing, there is an increase in brightness because of the behavior of the eye. The eye does not behave as an integrating photometer, but as a partially integrating and partially peak reading photometer. As a result, the eye perceives a brightness that is somewhere between the peak and the average brightness

Figure 5.



The net result is that a low duty cycle high intensity pulse of light looks brighter than a DC signal equal to the average of the pulsed signal. Therefore the practical benefit of multiplexed operation is an improvement in display visibility for a given average power consumption besides the lower cost. The brightness variation from segment to segment and digit to digit is also reduced by time-sharing. The gain in brightness over DC operation can be as much as a factor of 5 at low duty cycles of 1 or 2 percent, and peak currents of 50 to 100 mA.

A number of factors must be considered when deciding on the design of a multiplexed display. Besides the optical output, thermal considerations are very Important.

Most 1⁄4" size LED numerics are rated at 30 mA DC maximum per segment. Under pulsed operation, higher currents can be used provided several thermal considerations are taken into account.

(1) The average power dissipation must not exceed the maximum rated power.

(2) The power pulse width must be short enough to prevent the junction from overheating during the pulse. This implies that the pulse width must get shorter as the amplitude increases.

Present experience indicates that for pulses of 10 µs, the amplitude should be limited to 100 mA maximum. Shorter pulses of higher amplitude may be used but the circuit problems become severe if the pulse width is very short.