Build a TV Readout Device for Your Microprocessor

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A television set readout for your microprocessor has many attractive advantages. The TV readout is vastly faster, quieter, and even lighter, than the usual Teletype based design. Since it is an electronic rather than mechanical device, less service and maintenance are required. Much more data may be contained on a television screen than on front panel readouts.

The precise design of the television driving circuitry (interface) can take on a considerable number of forms. Some considerations are:

- Number of horizontal characters.
- Number of vertical characters.
- Upper case only, or upper and lower case text.
- Character generation format:
  row or column scan.
  5 x 7 dot matrix, 7 x 9 dot matrix or?
- Alphanumeric only, or alphanumeric and graphic formats?
- Converted home TV set or commercial TV monitor?
- Separate TV buffer memory or TV buffer shared with main memory?
- Shift registers for memory, or programmable RAM?
- Multiple video pages or single display?
- Interlaced scan or non interlaced?
- Hardware or software cursor, or no cursor?

Rather extensive list, isn't it? Understandably, a large number of designs have appeared recently, and many more will be seen. Every design has some advantages, some disadvantages.

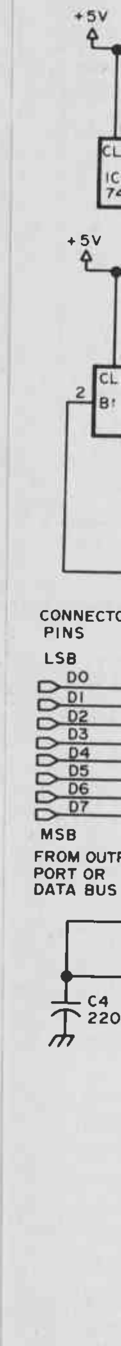
The 5 x 7 dot television display circuit in the June 1976 BYTE [*page 16*] is an example of a number of the above design alternatives. The 5 x 7 dot 2513 is a rugged, low cost character generator. The MM5320 is a fairly easy way to generate an interlaced signal. Programmable random access memory provides a random and faster screen update capability compared to the shift register "TV typewriters" of a few years ago.

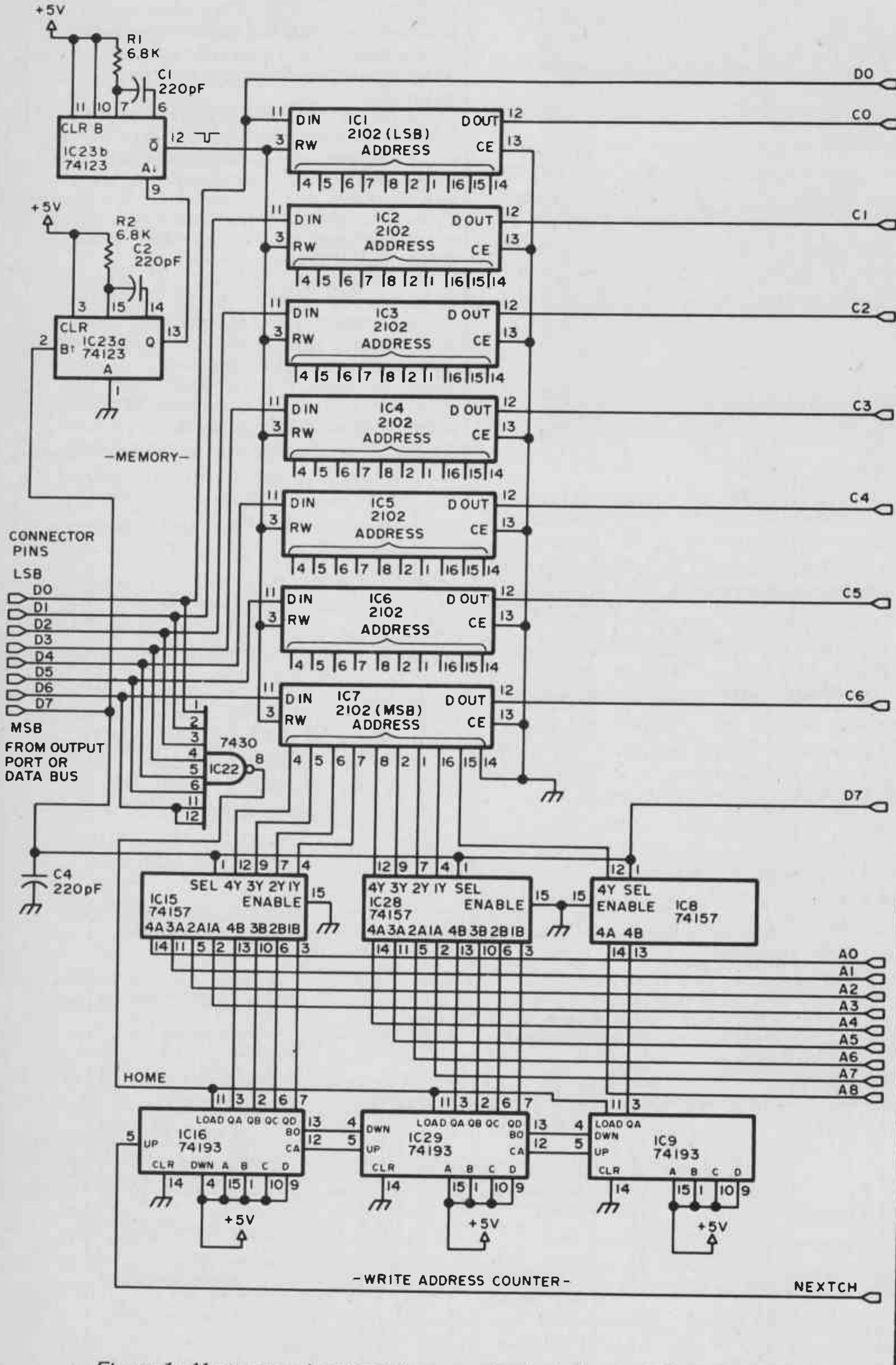
Major Features

The television display design shown in this article has several major departures from previously published designs. The June 1976 BYTE article on "A Systems Approach to a Personal Microprocessor" [*page 32*] stresses the need to keep various system elements independent in order to avoid unnecessary obsolescence. By using a simple parallel interface and making refresh memory part of the design, this television display achieves independence from a particular computer and bus design. This same display is also useful in such items as terminals, TV typewriters, and large computers.

A Motorola MCM6571L character generator is used as the heart of the Digital Group as well as several other video display systems. This character generator provides a 7 x 9 dot matrix character with automatic character shift for lower case characters such as g,j,y, etc, which extend below the base line, making an effective 7 x 13 dot matrix.

Thirty-two characters per line by 16 lines give a total of 512 characters on the screen. Endless arguments can result when screen formats arise. The 32 x 16 format was chosen to achieve the clearest and simplest (hence lowest cost) system. The more characters per line, the more television bandwidth is required. This system requires a TV monitor with better than 6 MHz bandwidth. A system with 64 characters per line would require a 12 MHz monitor, etc. Since the system was designed to minimize costs, a





+5 POWER SUPPLY PINS

Number	Type	+5V	GND
IC1	2102	10	9
IC2	2102	10	9
IC3	2102	10	9
IC4	2102	10	9
IC5	2102	10	9
IC6	2102	10	9
IC7	2102	10	9
IC8	74157	16	8
IC9	74193	16	8
IC10	74193	16	8
IC11	7404	14	7
IC12	74193	16	8
IC13	7400	14	7
IC14	7400	14	7
IC15	74157	16	8
IC16	74193	16	8
IC17	74193	16	8
IC18	7410	14	7
IC19	7404	14	7
IC20	7420	14	7
IC21	74193	16	8
IC22	7430	14	7
IC23	74123	16	8
IC24	74193	16	8
IC25	7430	14	7
IC26	7401	14	7
IC27	74L00	14	7
IC28	74157	16	8
IC29	74193	16	8
IC30	MCM6571L	2	13
IC31	74165	16	8
IC32	74193	16	8

Figure 1: Memory and write address counter logic for the TV readout design. The inputs to this circuit are at the left, labelled D0 to D7 corresponding to the data lines of a typical latched output data port. The connections to figure 2 include D0 and D7, memory outputs C0 to C6, and video timing chain address lines A0 to A8.

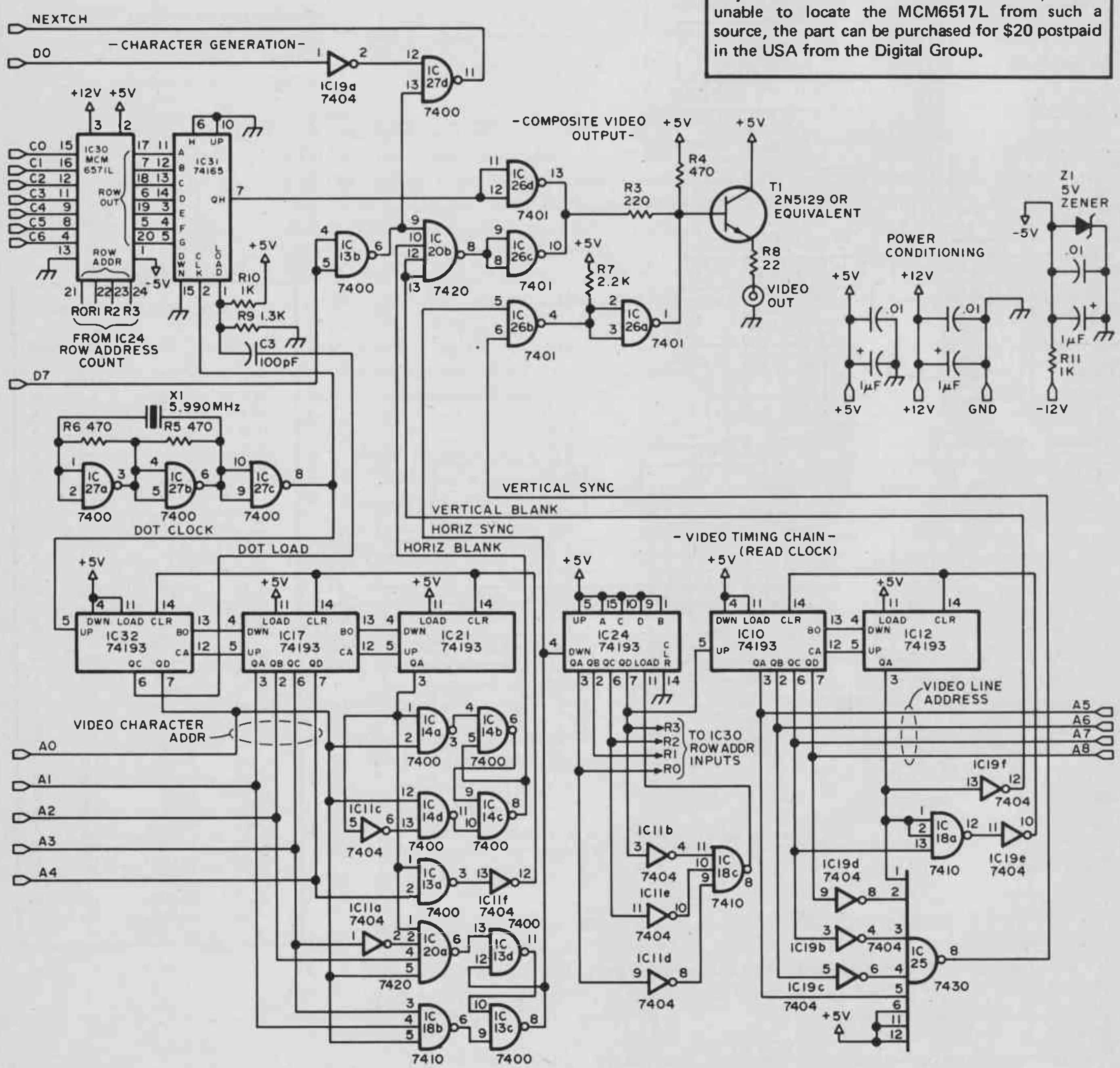
Figure 2: Character generation, composite video output and video timing chain logic for the TV readout design. The output of the TV readout is the composite video signal which drives a monitor or modified standard television set through a coaxial cable. The character generation logic consists of a read only memory, IC30, to translate character patterns into horizontal rows of dots, and the shift register, IC31, which sequences the bit by bit output of the row of dots. The video timing chain is a series of counters driven by the 5.990 MHz crystal, which cycles through the memory section of figure 1 and controls operation of the display.

A Note About Construction

The circuit shown in figures 1 and 2 is complete, and can be constructed in any well equipped home hardware laboratory using point to point soldering, home brew printed circuits, Vector wiring pencils, or wire wrap as an interconnection technique.

For those who wish to take advantage of construction using a circuit board and a complete set of electronic parts, Dr Suding's TV readout and the cassette interface described in his article on page 46 of July BYTE are available in a combined kit form for $130, postpaid in the USA. Contact the Digital Group Inc, PO Box 6528, Denver CO 80206, for information on this product.

For home brewers, the only part which might be difficult to find in surplus markets is the Motorola MCM6517L character generator chip. This package is available over the counter at many major electronics trade distributors. If you are unable to locate the MCM6517L from such a source, the part can be purchased for $20 postpaid in the USA from the Digital Group.



home black and white television set can be easily modified [*page 20, October 1975 BYTE*] and will satisfactorily meet the 6 MHz requirement. Sixteen rows of characters allow use of a non-interlaced sync system for lower cost. My own preferred TV display formats are either a 32 x 16 character system or the 80 x 24 character format. However, the 80 horizontal characters will require an expensive monitor to achieve the 15 MHz TV bandwidth and critical corner focus requirements.

The character memory can be of several formats, but this system uses a self contained programmable memory buffer which is loaded sequentially from the driving 8 bit output port of the microprocessor, or an ASCII keyboard. Some systems permit data readback from the TV readout system, but a greater cost is involved, and a mirror image buffer in the computer's programmable memory will produce the same result. Use of programmable random access memory in the TV readout permits very fast loadings, as fast as the system can output data. The typical update time for a total of 512 characters is under 5 ms. How far under 5 ms depends on the driving software and microprocessor used.

Cursors and cursor control may be performed in hardware or software. The approach of this system is to use software for the most part, which results in lower cost hardware. Cursor inserting subroutines are then used as needed.

So much for system design alternatives.

TV Readout Description

This TV readout consists of five interacting sections. They are memory, character generation, composite video output, video timing chain, and write address counter. The memory section (figure 1) consists of seven 2102A-2 or faster 1 K memories. Only one half of each memory is used, giving a possible storage of 512 seven bit ASCII characters. The microprocessor, keyboard, or some attached circuit writes the characters one by one into the 2102s, and then the TV readout continuously displays these characters until either more characters are entered, or the circuit is turned off.

The character generation circuit (see figure 2) consists of two integrated circuits, the MCM6571L character generator, IC30, and the 74165 shift register used to convert from parallel to serial. The 6571 takes the seven bit ASCII character coming from the memories and outputs 7 dots making up a character row for each of 13 potential rows making up each character. The 74165 loads all 7 dots into its internal memory, and then outputs these dots one at a time for serial transmission to a TV set. For more information on TV character generators, I would suggest reading an excellent article by Don Lancaster in June 1974 *Radio Electronics* [*pages 48-52*], or the June 1976 BYTE magazine article by C W Gantt [*page 16*].

The video output section uses a 7401 open collector NAND gate and a driver transistor to produce a low impedance composite video signal. The output is around 3 V peak to peak with about a 1/2 V horizontal and vertical sync and blanking pedestal.

The read clock (see figure 2) is the source of master control for the various sections. Starting from an initial frequency of 5.990 MHz, a countdown chain of three 74193s (ICs 32, 17, and 21) produce an 8 μs horizontal sync when gated by IC11a, IC20a, IC18b, IC13c and IC13d. A 41 μs horizontal blanking circuit prevents loss of characters at the edges of the screen, and is produced by the gating action of IC14, IC11c, IC11f and IC13a. The resultant horizontal frequency is 15,598 Hz, somewhat lower than the standard 15,750 Hz, but usually only requires trimming horizontal hold slightly, if at all.

The vertical countdown chain uses three more 74193s (ICs 24, 10 and 12) to obtain a final vertical frequency of 60 Hz, the same frequency as the AC line to avoid hum roll and wobble problems on low cost televisions. IC19b, IC19c, IC19d and IC25 produce an 820 μs vertical sync pulse, IC18a and IC19e detect state 20 of IC10 and IC12, counting lines 0 to 19 and giving four line periods for vertical retrace. The inverter IC19f produces a 3.5 ms vertical blanking

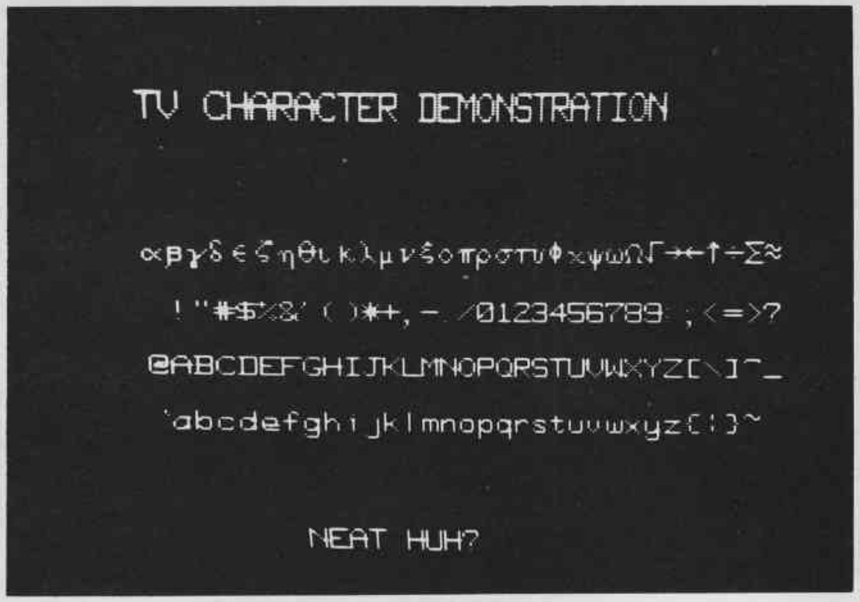


Photo 1: A test demonstration of Dr Suding's TV readout, shown in schematic form as figures 1 and 2. The test pattern consists of the four lines in the center which cycle through the possible binary combinations of characters. The differences in line width between the top line and the other lines are caused by non-linearities in the monitor used for this photograph.

pulse during states 16 to 19 of the counter IC10 and IC12.

As if these operations weren't enough, part of the video timing chain, counter IC24, tells which of the 13 lines in a character is being currently accessed. The counter IC32 keeps track of shifting and loads the 74165 when the row of 7 dots is available from the 6571. The 5.990 MHz signal then shifts out 8 dot periods (the 8th one is a horizontal space between characters) before the next dot load command occurs. All of these timings are very critical during the design phase; but since the circuit is digital, the builder should have no problems, since no adjustments are needed. The video timing chain counters develop a 9 bit address that controls which of 512 characters is currently being presented to the 6571 for dot encoding. This is routed to memory through 74157 multiplexors IC15, IC28 and IC8 except during write clock time.

I thought you'd never ask about the write clock. Well, it controls the entry of the

Figure 3:

Check Out Notes

The TV readout should be assembled according to your preferences (see "A Note About Construction") using sockets for all integrated circuits. These notes suggest a procedure for orderly testing of the new TV readout.

1. **Power supply.** Start checkout after all wiring has been completed, but before any integrated circuits have been inserted into sockets. Measure the resistance between ground and the other voltage supply pins. A very low resistance indicates a bad bypass capacitor, a solder bridge, or some other form of short circuit between the supply voltage and ground.

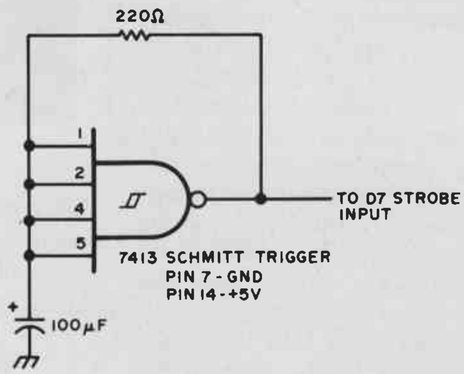
2. **TTL integrated circuits.** Insert all the integrated circuits of the TV readout except the memories (2102s, IC1 to IC7) and the character generator (MCM6517, IC30). Measure the resistance between the ground and the +5 V supply pin, noting its value; reverse the ohmmeter leads and remeasure. A shorted reading in either direction indicates a bad integrated circuit, and nearly equal readings in both directions indicates that at least one integrated circuit has been plugged in in reverse.

3. **Initial power up.** Temporarily ground the most significant bit input pin (D7 in figure 1), and connect the video output to a commercial TV monitor, or a TV set which has been modified to act as a monitor. Turn on the +5 V power. You should see 32 white vertical columns on the screen. (Refer to the "Diagnosis of Ailing Readouts", section 2, if this does not happen.) Turn off +5 V power.

Connect up the +12 V and -12 V power supplies, then turn on all power again. Verify the proper voltages on the MCM6517L socket, IC30: Pin 1 should have -5 V, pin 2 should have +5 V and pin 3 should have +12 V. Turn off power again.

4. **Now plug in the MOS parts:** The seven 2102 memory integrated circuits and the MCM6517 character generator read only memory. (The temporary ground jumper for the D7 input, and the video monitor output are still attached.) This time, when power is turned on, you should see a random display of 512 characters on the screen. The actual character at each location is determined by the chance power on initialization of each bit location, and cannot be predicted in advance.

5. **Testing:** Complete testing is now possible under computer control or by using a breadboard input device. If you use microprocessor control, simply wire the inputs to the TV readout to an 8 bit output port, load the software of listing 1 (if you have an 8080 or Z-80; write equivalent programs for other processors if necessary), and write some simple programs to generate known data and load that data into the display.



A test setup for manual verification of the display. The Schmitt trigger integrated circuit, a 7413 NAND function, has an RC feedback network to cause oscillations. This logic oscillator is used to drive the strobe input continuously, so that memory will be filled with a constant character pattern if that pattern's ASCII code is presented on input pins D0 to D6.

If it is desired to test the TV display without a microprocessor, the oscillator of figure 3 can be used to drive the input strobe pin, D7. Then temporarily tie all the other data pins to the +5 V supply through a 1 k resistor. Verification of the operation of the display can be obtained by grounding bits D0 through D6 of the input (the 1 k pullup resistors protect the power supply). The following table gives the characters which should fill the screen for each case:

Pin to Ground	Character	Octal Code
D0	~	376
D1	}	375
D2	{	373
D3	w	367
D4	o	357
D5	_	337 (underscore)
D6	?	277

characters from your external source into the 2102 memory bank. Several alternatives in character entry are possible, yet give the user a very capable unit, particularly when using a microprocessor, or even mini, midi, or maxi processors.

A sequential entry system is utilized. A home reset control signal (denoted "■") is developed by IC22 when it detects all of the 8 input lines high ("1"). The write address counter of IC16, IC29 and IC9 is then preset so that the next character to be entered will result in its being displayed as the top leftmost character on the screen. The second character will be viewed to the right of the first, . . . until on the 33rd character a new

Table 1: Character graphics, octal codes and binary codes for the TV readout.

Char	Octal	Binary*	Char	Octal	Binary*
α	200	10 000 000	@	300	11 000 000
β	201	10 000 001	A	301	11 000 001
γ	202	10 000 010	B	302	11 000 010
δ	203	10 000 011	C	303	11 000 011
ε	204	10 000 100	D	304	11 000 100
ζ	205	10 000 101	E	305	11 000 101
η	206	10 000 110	F	306	11 000 110
θ	207	10 000 111	G	307	11 000 111
ι	210	10 001 000	H	310	11 001 000
κ	211	10 001 001	I	311	11 001 001
λ	212	10 001 010	J	312	11 001 010
μ	213	10 001 011	K	313	11 001 011
ν	214	10 001 100	L	314	11 001 100
ξ	215	10 001 101	M	315	11 001 101
ο	216	10 001 110	N	316	11 001 110
π	217	10 001 111	O	317	11 001 111
ρ	220	10 010 000	P	320	11 010 000
σ	221	10 010 001	Q	321	11 010 001
τ	222	10 010 010	R	322	11 010 010
υ	223	10 010 011	S	323	11 010 011
φ	224	10 010 100	T	324	11 010 100
χ	225	10 010 101	U	325	11 010 101
ψ	226	10 010 110	V	326	11 010 110
ω	227	10 010 111	W	327	11 010 111
Ω	230	10 011 000	X	330	11 011 000
√‾	231	10 011 001	Y	331	11 011 001
→	232	10 011 010	Z	332	11 011 010
←	233	10 011 011	[	333	11 011 011
↑	234	10 011 100	\	334	11 011 100
÷	235	10 011 101	]	335	11 011 101
Σ	236	10 011 110	⌐	336	11 011 110
≅	237	10 011 111	—	337	11 011 111
blank	240	10 100 000	'	340	11 100 000
!	241	10 100 001	a	341	11 100 001
"	242	10 100 010	b	342	11 100 010
#	243	10 100 011	c	343	11 100 011
$	244	10 100 100	d	344	11 100 100
%	245	10 100 101	e	345	11 100 101
&	246	10 100 110	f	346	11 100 110
'	247	10 100 111	g	347	11 100 111
(	250	10 101 000	h	350	11 101 000
)	251	10 101 001	i	351	11 101 001
*	252	10 101 010	j	352	11 101 010
+	253	10 101 011	k	353	11 101 011
,	254	10 101 100	l	354	11 101 100
-	255	10 101 101	m	355	11 101 101
.	256	10 101 110	n	356	11 101 110
/	257	10 101 111	o	357	11 101 111
Ø	260	10 110 000	p	360	11 110 000
1	261	10 110 001	q	361	11 110 001
2	262	10 110 010	r	362	11 110 010
3	263	10 110 011	s	363	11 110 011
4	264	10 110 100	t	364	11 110 100
5	265	10 110 101	u	365	11 110 101
6	266	10 110 110	v	366	11 110 110
7	267	10 110 111	w	367	11 110 111
8	270	10 111 000	x	370	11 111 000
9	271	10 111 001	y	371	11 111 001
:	272	10 111 010	z	372	11 111 010
;	273	10 111 011	{	373	11 111 011
<	274	10 111 100	⌇	374	11 111 100
=	275	10 111 101	}	375	11 111 101
>	276	10 111 110	~	376	11 111 110
?	277	10 111 111	"Home"	377	11 111 111

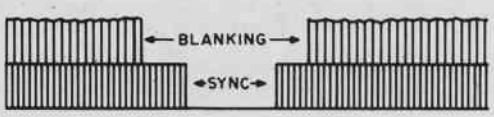
*The low order 7 bits of the binary representation map into the ASCII graphics where such graphics are defined. The high order bit is always a "1" value to act as a strobe in the software of TVOUT shown in listing 1.

Diagnosis of Ailing Readouts

1. Troubles – General
   - One of the more difficult troubles to find is an IC pin which was bent under the integrated circuit when it was inserted. Any unusual pressure when inserting an integrated circuit should be investigated.
   - Check continuity. Your wiring should be correct. If soldering is used, as in printed circuit assembly, check to make sure all joints are in good shape.
   - When troubleshooting with an oscilloscope probe, measure from the *top* side of the integrated circuit, not the bottom, to eliminate the possibility of being misled by a pin which is bent under or a defective socket.
   - Before ever plugging in any integrated circuits, always measure the voltages at the terminals of the display board and at the power pins of the more expensive integrated circuits, like the MCM6571.
   - When handling integrated circuits, avoid static charges. Run your house humidity high, and ground yourself by touching a grounded chassis before touching the integrated circuits.

2. When initially checking out, if no white columns appear on the screen at step 3, the following may be a cause of the problem.
   - Bad connection between TV output connector pin and TV.
   - Temporary jumper from input D7 pin to ground not connected.
   - Crystal not oscillating. Check for pulses at pin 1 of IC27.
   - Horizontal countdown chain defective. Successively measure output at pin 3 of IC32, IC17 and IC21. Each should be progressively lower in frequency.
   - Vertical countdown chain defective. As above, but measure pin 3 of IC24, IC10 and IC12.
   - Defective video mixer. Look for pulses at pins 1 and 13 or IC26.

3. Initial checkout pattern (step 3) is poorly defined or lacking synchronization. In this case the following comments might apply.
   - TV could be overloaded by the ≅ 3 V of video. Cut the level by adding a series resistor of 10 ohms to see if sync and video stabilize.
   - Check for horizontal and vertical sync and blanking pulse at connector pin 16. A 75 ohm load should be attached. The pattern should look like this:



   a. If horizontal sync is defective, check IC11, IC20, IC18 and IC13.
   b. If vertical sync is defective, check IC19 and IC25.
   c. If horizontal blanking is defective, check IC11, IC13 and IC14.
   d. If vertical blanking is defective, check IC19.

4. No characters at step 4 of the checkout procedure. Look for:
   - Missing voltages at the MCM6571 (IC30).
   - Defective character generator.
   - Defective 74165 (IC31).
   - Defective logic signals to and from IC30 and IC31. All inputs and outputs should be pulsing at valid TTL levels (0 to 0.8 V = low; 2 to 5 V = high).

5. Wrong character(s) in display when driving from computer or manual testing of step 5 in checkout.
   - Miswired or misjumpered input.
   - Defective memory IC. Note the bit difference between the intended character. IC1 is the memory for the Least Significant Bit (LSB) of the character . . . and IC7 is the Most Significant Bit's (MSB) memory.
   - Defective 74157(s), IC8, IC15 and IC28.

6. "Twinkling" characters on TV. The source of this problem could be:
   - Slow memories. 650 ns or faster 2102s must be used.
   - Overheated memories. Access times increase with heat.
   - Wrong pulse levels at pin 1 of 74165 (IC31). A base level of about 2.5 V with short positive and negative going spikes should be seen.
   - Defective character generator, IC30.
   - Incorrect timing components on 74123, IC23.

7. Won't write characters into memory of TV readout. Look for:
   - Missing strobe pulse, or continuous level on D7 input.
   - No write pulse from 74123. Measure at pin 12 of IC23, looking for an ≅ 600 ns negative going pulse. Connecting the D7 input to a ≅ 50 kHz TTL clock will permit viewing on lower cost oscilloscopes.
   - Write clock not toggling. With above temporary oscillator inputting to D7, look for pulses at pin 3 of IC16, IC29 and IC9.
   - Defective memory address multiplexers, IC15, IC28 and IC8.

8. Extraneous characters can be caused by:
   - Noise on the input lines to the memory, particularly on the D7 line. A 220 pF condenser (C4) is used on D7 to suppress most noise sources. More or larger condensers may be required in extreme cases. This trouble often shows up as an α appearing on the screen when another port is addressed.
   - Data sent to the TV character generator faster than it can handle. Data must be valid for 1.5 us following the rise of D7 strobe. Faster data rates can be handled by reducing the value of the condensers in the 74123 write strobe singleshot. Alternatively, a data hold loop in your program, consisting of NOP instructions, can slow the data output to the readout.
   - Defective or slow memories. Look at the bit pattern of the extraneous character to determine if a single memory is bad in a single or several data locations.
   - More bypassing required. Power supply conditioning is shown in figure 2. Look at the power supply with a high speed scope – if excessive voltage glitches are present, add capacitance.

line appears, displaying the 33rd character. Up to 512 characters are thus sequentially entered and displayed. If a 513th and following characters are entered, the address wraps around so that an overwrite condition results: New characters start appearing at the top left corner of the screen. The display address may be reset to the home position at any time. Screen erase is accomplished either by loading 512 or more ASCII "spaces" (octal 240) followed by the home reset (octal 377), or by issuing the home reset followed by exactly 512 ASCII spaces, the latter being preferable.

Memory writing occurs when the MSB goes high. The memory address multiplexors (IC15, IC28, and IC8) then use the write address counter to control the memory address lines, interrupting normal display activity. 600 ns later, a 600 ns strobe pulse writes the new character into memory.

An excellent idea was suggested by Phil Mork in the *Digital Group Clearinghouse* to utilize a parallel logic path to step the write address counter without writing a character. Using a cycle of 511 write address steps, a blank, 511 write address steps and a non-blank character, a blinking "pseudo cursor" effect is obtained without the usual expense of a number of comparators. This software "blink" may be easily implemented with a final result indistinguishable from a hardware cursor. The write address stepping logic consists of IC19a and IC27d which detect the presence of a "1" in the least significant bit while the most significant bit is held low. This toggles the write address counter without firing the 74123 write strobe (IC23b). Disable the "pseudo cursor" when using a direct keyboard input. Do this by disconnecting pin 12 of IC27 from IC19, and tying pin 12 to +5 V (logical 1).

8080/Z80 Driving Software

This television display can be driven by a microprocessor's 8 bit output port. In the Digital Group systems, we use port 0 for this function. Listing 1 shows code for the routines CLEARTV, SPACE, and TVOUT to show how the software drivers are designed.

The main subroutine is labeled TVOUT and is located at <0> 372. The programmer merely loads the A register with one of the characters from the list in table 1 and calls the TVOUT subroutine. The codes in table 1 include all the standard upper and lower case ASCII codes, but have the high order bit of an 8 bit word set to "1". For those characters in table 1 which have ASCII graphics, subtracting 2 from the leftmost digit will give the equivalent 7 bit ASCII code (with the high order eighth bit assumed to be zero).

The instruction at <0> 370 will load the "space" character for you, so to get a space on the screen, merely call SPACE at address <0> 370.

Before attempting to write any character on the screen, the user must know where on the screen the character will appear. A third included subroutine starting at <0> 343 called CLEARTV will reset the write address counter to the home position and clear the 512 character screen. The next character entered after this subroutine will appear at the top leftmost position on the screen.

Listing 1: Utility software for driving the TV readout with an 8080 or Z80 system. This listing gives the CLEARTV, SPACE and TVOUT functions, a total of 28 bytes. The CLEARTV operation simply homes the display, then writes 512 spaces leaving a blank screen and the write address counter pointing to the upper left corner of the screen. The SPACE subroutine simply loads a space code into the accumulator (see table 1) then falls through into TVOUT. TVOUT simply outputs the value in the accumulator, then clears the accumulator and outputs all zeros so that the write strobe (D7) is turned off completing the write operation. This routine assumes a latched output port.

Split Octal Address	Octal Code	Label	Op.	Operand	Commentary
<0> 343	076 377	CLEARTV	MVI	A,377	A := '■' [set up home reset character];
<0> 345	315 372 <0>		CALL	TVOUT	write character [resets write address];
<0> 350	006 000		MVI	B,0	} BC := 2000 [set loop count to split octal equivalent of 512];
<0> 352	016 002		MVI	C,2	
<0> 354	315 370 <0>	CLEAR	CALL	SPACE	write one space on screen;
<0> 357	015		DCR	C	C := C – 1 [low order count];
<0> 360	302 354 <0>		JNZ	CLEAR	if not C = 0 then reiterate the loop;
<0> 363	005		DCR	B	B := B – 1 [high order count];
<0> 364	302 354 <0>		JNZ	CLEAR	if not B = 0 then reiterate the loop;
<0> 367	311		RET		return with screen clear, write address counter pointing to home position;
<0> 370	076 240	SPACE	MVI	A,240	A := ' ' [load one blank character code];
<0> 372	323 000	TVOUT	OUT	0	(port 0) := A;
<0> 374	257		XRA	A	A := 0 [turns off strobe pulse in bit 7];
<0> 375	323 000		OUT	0	(port 0) := A;
<0> 377	311		RET		return from SPACE or TVOUT;

Entry points:

CLEARTV: Called with no parameters when TV display screen is to be cleared completely and left in the "home" (upper left) position. Uses registers A, B and C.

SPACE: Called when a space (ASCII 040, 240 from table 1) is to be sent to the TV display. Uses register A.

TVOUT: Utility output routine to transfer contents of A (high order bit assumed "1") to the TV display and increment the write address counter. Uses register A as input parameter, destroys its value leaving 0.

Conclusion

This television display design provides a versatile and essentially self contained circuit to provide the key output device of a small and inexpensive computer system. It can be built from scratch in the typical experimenter's laboratory or from a kit provided by Digital Group. Due to its use of an extended character set with 127 symbols including upper and lower case, special characters and Greek, the display will prove quite useful in a variety of applications.■