Digital Waveform Generator using EEPROM ROM

By

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Abstract: For a long time TTL (Transistor Transistor Logic) integrated circuits (7400 series) have been used to design digital circuits; with the creation of ROM (Read Only Memory), SPLD (Simple Programmable Logic Devices), CPLD (Complex Programmable Logic Devices) and FPGA (Field Programmable Gate Array), digital design has been easier than ever. This paper discusses the programming and simulation of ROM family devices such as EPROM (Erasable Programmable Read Only Memory), EEPROM (Electronically Erasable Programmable Read Only Memory), and Flash ROM and how to integrate them to designing a digital waveform generator. We are using PSpice software to program ROM family devices. The PSpice manual provides little information about the procedures of ROM programming. The following steps will include programming the chip in PSpice, which is similar to programming the actual ROM devices.

I. Introduction

ROMs are memory devices used to store data permanently [1]. ROMs hold a bit pattern for each distinct address applied to their inputs. In dedicated microcontroller applications, often used in equipments like oscilloscope and logic analyzer, ROMs are used extensively. ROMs are generally used for read-only operations and are not written to after they are initially programmed. EEPROMs store their bit as charges held on gates and hence can be erased and reprogrammed using either UV light or voltage [2].

In an EPROM we have a grid of columns and rows [3]. The cell at each intersection has two transistors. The two transistors are separated from each other by a thin oxide layer [4]. One of the transistors is known as the floating gate and the other as the control gate. The floating gate's only link to the row (wordline) is through the control gate [5]. As long as this link is in place, the cell has a value of 1. To change the value to 0 requires a curious process called Fowler-Nordheim tunneling. Tunneling is used to alter the placement of electrons in the floating gate [6]. An

electrical charge, usually 10 to 13 volts, is applied to the floating gate. The charge comes from the column (bitline), enters the floating gate, and drains to a ground.

II. Programming Description

Task 1-Programming a ROM device using PSpice ROM map

This shows how to create a memory map to program a ROM in PSpice for any types of waveforms using a 32Kx8 ROM from the PSpice [7] Breakout library to create a digital waveform generator from 16 pages of waveform inputs and outputs.

Task 2-Programming a ROM device using Intel Hex File

Using the TTROM compiler, create a Hex file to download into a device programmer. Then, program a ROM chip.

Task 1

Using Excel, create a memory map for the application then calculate how many memory locations needed for the ROM. First the examination of input waveforms takes place and then, they need to be divided into 32 pieces to effectively recreate the original waveforms. This meant that we would be using 32X16 = 512 locations of ROM. Each one of the outputs is assigned to an input waveform as shown below in Figure 1.

Table 1 - Memory Map for 512 X 8 ROM

Figure #	Memory Address (Hex)	Out 0	Out 1	Out 2	Out 3	Out 4
8-9	000-01F	E1not	A0	A1	A2	N/A
8-16	020-03F	I7not	I8not	I9not	N/A	N/A
8-19	040-05F	Einot	I6not	I7not	N/A	N/A
10-6	060-07F	S	R	Q	N/A	N/A
10-10	080-09F	G	S	R	N/A	N/A
10-11	0A0-0BF	G	S	R	N/A	N/A
10-13	0C0-0DF	G	D	N/A	N/A	N/A
10-16	0E0-0FF	E0-1	D0	N/A	N/A	N/A
10-19	100-11F	Ср	Sdnot	Rdnot	D	N/A
10-21	120-13F	Ср	Sdnot	Rdnot	D	N/A
10-21 (continued)	140-15F	Ср	Sdnot	Rdnot	D	N/A
10-31	160-17F	Cpnot	J	K	N/A	N/A
10-34	180-19F	Cpnot	Sdnot	Rdnot	J	K
10-36	1A0-1BF	Ср	Sdnot	Rdnot	J	K
10-38	1C0-1DF	Ср	Sdnot	Rdnot	J	Knot
10-43	1E0-1FE	Trigger	Rdnot	Data	N/A	N/A

MEMORY MAP FOR 512 x 8 ROM

N/A = Not Applicable

*Outputs not utilized held low in the ROM programming

** Outputs 5,6,7 are not needed for this experiment.

Creating the schematic in PSpice

First select a ROM32X8break from the breakout library as shown below in Figure 1.

0	Orca	d Cap	ture -	Lite E	dition -	[7 - (SC	HEMATIC1	: PAGE1)]							_ 8 ×
	<u>F</u> ile	<u>E</u> dit	⊻iew	<u>P</u> lace	<u>M</u> acro	P <u>S</u> pice	<u>A</u> ccessorie	es <u>O</u> ptions	: <u>W</u> indow	<u>H</u> elp						_ 8 ×
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11								27 A1:	3							
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											0	items select	ed	Scale=100%	X=4.90 Y=1.90)

Figure 1 - ROM 32 by 8 from breakout library

Second, add the clock section to count up to 512 and the bus for the outputs as shown below in Figure 2.



Figure 2 - Clock and 10 bit binary counter

Third, after creating the schematic, select the ROM chip and right click on it to bring up the "Edit PSpice Model" option, as shown below in Figure 3.



Figure 3 - Editing the ROM Model

Forth, for programming the ROM on the device line, we include the data on the DATA line as shown below in Figure 4.

ere a	sses	smer	nt pr	ojec	t 256	6 x 8	rom	- P9	Spic	e Mo	del	Edito	or Li	te -	(RO	M32	Kx8	Brea	k]												- 8	×
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.su	BCK	r R(DM32	2 Kx8	BBre	eak	A14	4 A:	13.	A12	A1:	1 A:	10.	A9 J	A8 .	A7 .	A6 .	A5 .	A4 .	A3 .	A2 .	A1 .	AO									٠
+							OE}	oar	07	06	05	04	03	02	01	00																
+							OP'	LIOI	NAL	: D1	PWR	=\$G_	DPI	WR 1	GNI	D=\$(G_D(GND														
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+				ROI	м_т:	IMII	ΝG																									
+				IO	STI	D																										
+				MN'	TYM2	XDL.	Y={]	MNT	YMXI	DLY]	} I(5_гі	EVE	L={:	10_1	LEVI	EL}															
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+07	07	07	07	07	06	06	06	06	06	03	03	03	03	03	05	05	05	05	05	01	01	01	01	01	04	04	04	04	04	04	04	
+07	07	07	07	07	06	06	06	06	06	04	04	04	04	04	00	00	00	00	00	02	02	02	02	02	03	03	03	03	03	03	03	
+01	01	01	00	00	00	04	00	00	00	01	01	00	00	00	02	02	02	04	02	04	00	00	00	01	00	00	00	00	00	00	00	
+05	01	03	03	01	05	04	04	03	05	01	03	03	00	02	02	00	00	02	03	0.0	01	00	00	00	00	00	00	01	00	00	00	
+01	01	01	01	01	03	02	02	02	02	00	01	01	03	01	01	01	00	02	00	01	01	03	03	03	01	01	00	00	00	00	00	
+01	03	03	01	01	00	02	02	00	00	01	01	03	03	03	n2	n2	00	00	00	01	01	01	01	03	n2	n2	n2	02	n2	02	02	
+04	04	06	06	07	07	OF	OF	OE	OE	OE	OF	OF	OB	OF	06	06	OE	OE	OF	OF	OB	OF	OE	OE	OE	OF	OF	OF	OF	OF	OF	
+0A	OA	OA	OA	OB	OB	OF	OF	OE	OE	OE	OF	OF	03	03	06	04	04	06	07	07	OF	07	06	06	OE	06	07	07	07	06	06	
+0E	OE	06	06	07	07	07	07	06	06	05	06	06	07	07	OF	OF	OE	OE	OA	OA	OB	OB	OF	OF	OE	OE	04	04	05	05	05	
+00	00	01	03	02	04	00	05	01	00	00	01	05	04	02	03	07	07	06	06	07	05	04	00	01	07	00	00	00	00	00	00	
+04	06	06	07	07	17	16	16	16	16	1F	1F	1F	1 E	1Å	1A	OF	OF	07	07	06	06	06	07	05	05	07	07	07	07	07	07	
+1A	1A	1E	1F	1F	1F	1F	1E	1E	16	16	17	17	17	17	16	OE	OE	OE	OF	07	07	07	06	16	16	17	17	OF	OF	06	06	
+0C	OE	OE	OF	OF	OD	OE	OE	OE	OF	1F	1F	1E	1E	1E	1F	1F	1F	1E	1E	1Å	1B	1B	1B	1Å	1A	1A	1Å	1A	1Å	1Å	1Å	
+01	07	06	06	07	07	03	02	02	03	07	07	00	02	03	07	03	02	06	07	03	06	06	07	07	03	02	02	02	02	02	02\$	
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Figure 4 - Programming the ROM in Model Editor

A. First remove the * sign, or the entire line will be considered a comment.

B. Next, enter "X\$" after the = sign. The X refers to Hex and the \$ signs are used to tell PSpice that's the beginning of the data.

C. Then put a \$ at the end of the data as shown above to tell PSpice the data is done.

Fifth, run the simulation in PSpice and examine the data to verify it is correct as shown below in Figure 5.



Figure 5 - The output file resulting from the binary counter

Creating an Intel Hex-File and Downloading Into a ROM Device Using Notepad for small files, run the TTROM [8] complier and create a Hex file to download into a device programmer [9].

First copy or input the data into Notepad as shown below in Figure 6.

D	ata1 -	Notepa	ł		_ 🗆 🗵
<u>F</u> ile	<u>E</u> dit	<u>S</u> earch	<u>H</u> elp		
aaa	a	00000	900		A
000	0	11111	101		
000	1	01010	101		
001	ម	00011	101		
001	1	44944	101		
010	0 1	11011	101		
010	1 A	01010	101		
011	ย 1	11001	101		
100	ด	00011	300		
100	ĩ	10101	111		
101	0	01010	900		
101	1	00001	111		
110	0	11000	111		
110	1	11111	111		
111	0	00000	900		
111	1	11111	111		

Figure 6 - Creating the ROM table in notepad

- 2. Run a DOS prompt window and go to the TTROM folder as shown below.
- 3. Enter the command: "tt2rom c:\ filename.txt"
- 4. The file has now been converted to Intel Hex format as shown below in Figure 7 [10].

🚜 MS-DOS Prompt		_ _ _ ×
Auto 💽 🔛 🖻 🔁 🔐 🗛		
C:\TT2ROM>DIR/W		
Volume in drive C has no label Volume Serial Number is 23DA-13F7 Directory of C:\TT2ROM		
[.] [] CHANGES BANKTX*1.GZ DRIVER.C ROADPA*1.GZ Test.tt text.c text.h	MAKEFILE Rom.c Tt2rom.c	README Rom.H Tt2Rom.exe
14 file(s) 1,749,743 bytes 2 dir(s) 35,123.89 MB free		
C:\TT2ROM>TT2ROM This is tt2rom version 2.06		
Usage: C:\TT2ROM\TT2ROM.EXE <file> (or 'help</file>	′ for assistance)	
C:\TT2ROM>TT2ROM C:\DATA1.TXT This is tt2rom version 2.D6		
1 ROM images to be written, 16 bytes per image Writing ROM #O to file 'C:\DATD.hex'		
C:\TT2ROM>		

Figure 7 - Running the TT2ROM program in DOS prompt

Note the actual Intel Hex file for the Digital Waveform Generator was not shown. This Figure is for reference, as shown below in Figure 8.

🗾 Dat0 - Notepad	
<u>File E</u> dit <u>S</u> earch <u>H</u> elp	
: 02 00 00 2 00 00 F C	<u>^</u>
10000000FD551D79D9F955CD18AF500FC7FF00FF29	
: 0000001FF	

Figure 8 - Intel Hex File created by TT2ROM Program

Task 2

Now the Intel Hex file that you created can be read into the input buffer of programming software like ICROMMASTER- LV48 [5].

The type of programmer used for this program run was the ICROMMASTER- LV48
(A) More information can be found at http://www.icetech.com/

2. Open programmer by selecting the icon for WinLV as shown below in Figure 10.

2. Open Intel Hex file loading buffer with Hex codes, as shown in Figure 9 and 10 [6].

🛷 ICE Te	chnol	ogy: W	′inLV	- M2	7C64	A - [l	Jntitl	ed]											_ <u>8</u> ×
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00000	000	FF	FF	FF	FF	FF	\mathbf{FF}	FF	FF	FF	FF	\mathbf{FF}	FF	FF	FF	FF	FF		
00000	010	FF	FF	FF	FF	\mathbf{FF}	\mathbf{FF}	FF	FF	$\mathbf{F}\mathbf{F}$	FF	FF	FF	FF	FF	FF	FF		
00000	020	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	030	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	040	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	050	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	060	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	070	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	080	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	•••••	
00000	090	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	OAO	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	IOB0	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	•••••	
00000	IOCO	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	UDU	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	UEU	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	F F	FF	FF	FF	FF		
00000	UFU	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	1100	FF FF	rr EE	rr EE	rr EE	rr EE	rr EE	rr EE	rr EE	FF	rr EE	11	rr EE	rr EE	rr EE	rr EE	rr EE		
00000	120	FF	FF	rr EE	FF	FF FF	FF FF	rr EE	F F	FF	FF	rr FF	rr FF	rr EE	FF FF	FF FF	FF		
00000	120	11 EE	F F	rr EE	FF FF	L L L	FF FF	FF FF	F F	L L L	F F	11	1 1 E E	11	FF FF	FF FF	FF FF		
00000	140		F F	rr FF	rr FF	rr FF	F F	F F	F F	rr EE	F F	1 1 E E	F F	11	FF FF	FF FF	FF FF		
00000	150		rr FF		L L L L	rr FF	F F F F	F F	F F	rr FF				rr FF	F F	F F F F	F F F F		
00000	1160		rr rr	rr FF	rr FF	rr FF	rr TT	rr vv	rr vv	rr rr	rr FF	rr rr		rr FF	rr rr	rr rr	rr rr		
00000	120		ГГ ГГ	7 7 7 7	rr rr	rr rr	rr rr	rr vv	rr vv	rr rr	rr vv	rr rr	77 77	rr rr	rr rr	rr vv	rr rr		
00000	120	FF	FF	FF	FF	FF	FF.	FF FF	FF	FF FF	FF	FF FF	FF	FF	FF	E E	FF FF		
00000	100	- F F	- T T 	E E	E E	L L	L L L L	FF FF	E E	E E	E E	L L L L	FF.	FF FF	E E	E E	FF FF		
00000	130	55	E E	FF	FF	E E	E E	55	FF	E.E.	E E	FF	FF	FF	E E	- F F	E E		
00000	180	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	100	FF	FF	FF	FF	FF	E E	FF	FF	E E	FF	FF	FF	FF	FF	FF	FF		
00000	100	FF	F F	FF	FF	E E	E E	FF	FF	E E	E E	E E	E E	E E	- F F	- F F	E E		
00000	1150	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	1150	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
00000	200	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF		
	200																**		
ST-MICR	US M2	/C			00	h	127CE	i4A							F. 00				
]8K.X8					28	9	R	8	J				venh	es at:	5.00	_			
	41.						1						_			Byt	e=0x0	0 BCRC=6C1C291F BSUM=3FC0 0000 Size=4M E	DIT
Start			× (90		G		77 10	ETe	chnol	ogy:	WinL	۷					± \$\$\$:00 PM

Figure 9 - EEPROM Programmer



Figure 10- Uploading file to EEPOM Programmer

3. The data buffer has the required information for our Digital Waveform Generator ROM chip in the program buffer starting at location 0000 Hex, as shown in Figure 11.

🛷 ICE Techno	ology: W	/inLV	- M2	7C64	A - [F	:\Scl	hool\	Proje	ect R(DM D1	₩G\/	\sses	sme	nt Pr	ojecl	: 256 X	8 R0M	1\DWG	Intel I	Hex	îile for R	0M]					_ E	
File Edit Vie	w Prog	ramme	er H	elp																								
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Byte	00	01	02	03	04	05	06	07	08	09	0A	OB	00	OD	0E	OF	0	12345	5678	9AB	CDEF							
00000000] 00	00	02	02	04	04	06	06	08	08	ΟA	ΟA	05	05	07	07												
00000010	01	01	03	03	05	05	06	06	00	00	02	02	0C	0C	0E	0E												
00000020	07	07	07	07	07	06	06	06	06	06	03	03	03	03	03	05												
00000030	05	05	05	05	01	01	01	01	01	04	04	04	04	04	04	04	•											
00000040	07	07	07	07	07	06	06	06	06	06	04	04	04	04	04	00		• • • •		• • •								
00000050	00 00	00	00	00	02	02	02	02	02	03	03	03	03	03	03	03	1.1	• • • • •		• • •								
00000060	01	01	01	00	00	00	02	00	00	00	01	01	00	00	00	02	•	• • • •		• • •								
00000070	02	02	02	02	02	00	00	00	01	00	00	00	00	00	00	00		• • • •		• • •								
00000080	03	03	01	01	00	04	04	04	05	05	05	01	00	00	02	02	1.1	• • • • •		• • •								
00000090	00 00	03	01	05	05	04	00	00	00	00	00	00	00	00	00	00		• • • •		• • •								
000000A0	05	01	03	03	01	05	04	04	04	05	01	03	03	03	02	02	•	• • • •	• • • •	• • •								
000000B0	00	00	02	03	01	01	00	00	00	04	04	05	01	00	00	00		• • • • •										
00000000	01	01	01	01	01	03	02	02	02	02	00	01	01	03	01	01		• • • •	• • • •	• • •								
UUUUUUUUUU	01	00	02	00	02	02	03	03	03	01	01	00	00	00	00	00	•	• • • •	• • • •	• • •								
UUUUUUEU		03	03	01	01	00	02	02	00	00	01	01	03	03	03	02	1.1	• • • • •										
000000F0		00	00	00	01	01	UI	UI	03	UZ OF	UZ	UZ	UZ	UZ OD	UZ	02		• • • • •		• • •								
00000100	04	04	00	05	07	07	UF	OF	OE	UE	OE	10	OF	UB	OF	00		• • • • •	• • • •	• • •								
00000110		UE	UE	Ur	UF	UB	UF	UE	UE	UE	OF	UF	OF	Ur	Ur	UF		• • • • •	• • • •	• • •								
00000120		O 4	OC OC	UA 07	UB 07	UB	UF 07	or	UE	OF	UE OC	UP 07	UF 07	03	03	06	1.1											
00000130	04	04	06	07	07	UF 07	07	05	06	UE	05	07	07	07	05	05		• • • • •										
00000140		UE OF	00	00	07	07	07	07	00	00	05	00	00	07	07	OF		• • • • •		• • •								
00000150		UE	UE 01	UA 0.2	DA 0.2	UB 04	UB	OF	or	UE	UE OO	04	04	03	05	05	1.1											
00000180		00	01	03	02	04	00	00	01	00	00	01	00	04	02	00		• • • • •		• • •								
00000170		07	00	07	07	17	16	16	16	16	100	100	100	117	1 2	17	•	• • • • •	• • • •	• • •								
00000180	04	00	00	07	07	1/	10	10	10	10	11	11	11	15	18	18												
00000190		12	15	15	10	10	15	107	100	16	16	17	17	17	17	16												
000001A0		14	11	11	11	11	11	16	16	16	17	17	17	17	17	10		• • • • •		• • •								
00000180		05	05	OF	07	07	07	00	10	10	15	15	15	15	15	15		• • • • •										
00000100	1 15	115	115	115	12	18	18	18	12	12	18	1 7	18	12	1 2	18	1.1											
00000100		11	16	16	07	10	10	10	18	14	18	07	00	18	18	18												
000001E0		07	00	00	07	07	03	02	02	03	07	07	00	02	03	02	•	• • • • •	• • • •									
000001F0	ਵਹ ਕੁਰੂ	모드	00	07 FF	00 77	00 FF	00 FF	07 EE	107	U U U U	UZ FF	UZ FF	UZ FF	UZ FF	UZ FF	52 FF												
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ST-MICROS M	27C			20	M	127CE	64A					Marif.		E 00														
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Figure 11 - Uploaded HEX codes

Next, select operations icon displaying several selections, as shown in Figure 12.

7 ICE Technolo	ogy: Win	ιL¥ -	- M27	rC64/	A - [U	Intitl	ed]																			_ 8	×
File Edit View	Progra	mme	r He	elp																							
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00000010	01	01	03	03	05	05	06	06	00	00	02	02	0C	OC	ΟE	0E											
00000020	07	07	07	07	07	06	06	06	06	06	03	03	03	03	03	05											
00000030	05	05	05	05	01	01	01	01	01	04	04	04	04	04	04	04											
00000040	07	07	07	07	07	06	06	06	06	06	04	04	04	04	04	00					•						
00000050	00	00	00	00	02	02	02	02	02	03	03	03	03	03	03	03					•						
00000060	01	01	01	00	00	00	02	00	00	00	01	01	00	00	00	02					•						
00000070	02 1	02	02	Op	erati	ions f	or de	evice	: M27	7C64	A																
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000000E0	02	nn	00																								
00000100	04	Π4	06																								
00000110	06 1	0E	0E	epr	rom8.I	LIB	V3.0	036	IMLV4	8 p	ort @	0x37	в														
00000120	OA I	ΟA	ΟA	OA	OB	OB	OF	OF	0E	0E	0E	OF	OF	03	03	06											
00000130	04	04	06	07	07	OF	07	06	06	ΟE	06	07	07	07	06	06											
00000140	0E I	0E	06	06	07	07	07	07	06	06	05	06	06	07	07	OF											
00000150	OF	0E	0E	ΟA	ΟA	ΟB	0B	OF	OF	ΟE	0E	04	04	05	05	05											
00000160	00 0	00	01	03	02	04	00	05	01	00	00	01	05	04	02	03											
00000170	07	07	06	06	07	05	04	00	01	07	00	00	00	00	00	00											
00000180	04	06	06	07	07	17	16	16	16	16	1F	1F	1F	1E	1A	1A											
00000190	OF	OF	07	07	06	06	06	07	05	05	07	07	07	07	07	07					•						
000001A0	1A	1A	1E	1F	1F	1F	1F	1E	1E	16	16	17	17	17	17	16			• • • • •	• • • • •	•						
000001B0	0E I	0E	ΟE	OF	07	07	07	06	16	16	17	17	OF	OF	06	06			• • • • •	• • • • •	•						
000001C0	OC I	0E	OE	OF	OF	OD	OE	OE	OE	OF	1F	1F	1E	1E	1E	1F					•						
000001D0	115	1F	1E	1E	1A	18	18	18	1A	1A	1A	1A	1A	1A	1A	1A		• • • •		• • • • •	•						
000001E0	01	07	06	06	07	07	03	02	02	03	07	07	00	02	03	07					•						
000001F0	03 0	U2 EE	06	07	03	06	06	07	07	03	02	02	02	02	02	02					•						
00000200	rr I	r r	rr	rr	rr	rr	rr	rr	rr	r r	rr	rr	rr	rr	rr	r r					•						
ST-MICROS M27	°C			_	M	12706	4A																				
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For Help, press F1															Byt	e=0×0)			BCRC=8	F995EA2	BSUM=3F	BE 1065	Size=4M		EDIT	
Start 🛛 🕎		3	9 🕰	۵	•		77 10	E Teo	hnolo	ogy:	WinL	۷	Do	ocume	enti -	Micros	oft W							} ∢€⊙_	7 5	4:08 Pf	м

Figure 12 - Operation selection

With parameters menu changes can be made to locations for data storage into ROM but in this case no changes are necessary so select accept, as shown below in Figure 13.

7 ICE Technolo	gy: W	inL∀	- M27	7C64	A - [U	Intitl	ed]																		_ 8	×
File Edit View	Progr	amme	er He	elp																						
0 🖻 🔚 🛛	ê 6	2 6	3 🕻	1 3	ξ 🗎		8		I 🐳	٠		ீங	<mark>,</mark> xx	۵ă	Å.	74 <i>M</i>	*** ***		O XXX XXXX XX O XXX B1B0 B0	** 81						
Byte	00	01	02	03	04	05	06	07	08	09	0A	OB	00	OD	0E	OF	0	12345678	9ABCDEF							F
00000000	00	00	02	02	04	04	06	06	08	80	ΟA	ΟA	05	05	07	07										
00000010	01	01	03	03	05	05	06	06	00	00	02	02	0C	0C	ΟE	ΟE										
00000020	07	07	07	07	07	06	06	06	06	06	03	03	03	03	03	05										
00000030	05	05	05	05	01	01	01	01	01	04	04	04	04	04	04	04										
00000040	07	07	07	07	07	06	06	06	06	06	04	04	04	04	04	00			• • • • • • •							
00000050	00	00	00	00	02	02	02	02	02	03	03	03	03	03	03	03	1.1	• • • • • • • •	• • • • • • •							
00000060	01	01	01	00	00	00	02	00	00	00	01	01	00	00	00	02	•		• • • • • • • •							
00000070	02	02	02	Οp	erati	^{ID} Ins	sert I	Parar	neter	s: Pr	ogra	mmi	ng)							
00000080	03	03	UI	0	perati	Vie	вw														_					
00000090	00	03	01				123			He								Cancel	Accept	Clos	8					
00000080	00	01	03				5 105 Mino () 26-06-0					_		0.0	1										
000000000	00	01	02			De	NICE 3	otait A	uuless											-						
000000000	01	0Ô.	02	il -		De	vice t	nd A	ddress						UXI	+++				_						
000000E0	01	03	03			Bu	ffer St	art Ac	Idress						0x0					_						
000000F0	02	00	00			Bu	ffer In	creme	ent						Eve	ery Byte										
00000100	04	04	06			Se	rial nu	mber	value						0x1	В										
00000110	06	0E	ΟE	epi	rom8.I	LI	1.010	, oo		- P		0.001	,	<u>р о</u>	000071	0100.	70 010									
00000120	ΟA	ΟA	ΟA	ΟA	OB	ΟB	OF	OF	0E	ΟE	0E	OF	OF	03	03	06										
00000130	04	04	06	07	07	OF	07	06	06	ΟE	06	07	07	07	06	06										
00000140	ΟE	ΟE	06	06	07	07	07	07	06	06	05	06	06	07	07	OF										
00000150	OF	ΟE	ΟE	ΟA	ΟA	OB	OB	OF	OF	ΟE	ΟE	04	04	05	05	05			• • • • • • •							
00000160	00	00	01	03	02	04	00	05	01	00	00	01	05	04	02	03		• • • • • • • • •	• • • • • • • •							
00000170	07	07	06	06	07	05	04	00	01	07	00	00	00	00	00	00		• • • • • • • • •	• • • • • • • •							
00000180	04	05	05	07	07	17	16	16	16	16	1F	1F	1F	1E	1A	1A		• • • • • • • • •								
00000190	10	13	117	117	100	100	100	117	15	105	107	17	17	17	17	107	1.1	• • • • • • • • •	• • • • • • • •							
000001A0	AL 07	AL 07	11	11	11	11	11	11	16	10	10	17	17	17	1/	10		• • • • • • • • •								
00000100	00	015	012	OF	07	07	07	00	10	10	11	1 5	115	115	15	116	1.1	• • • • • • • • •								
00000100	115	1F	115	1F	14	1B	18	18	14	1A	14	14	14	14	14	14										
000001E0	01	07	06	06	07	07	03	02	02	03	07	07	00	02	03	07										
000001F0	03	02	06	07	03	06	06	07	07	03	02	02	02	02	02	02	- 1									
00000200	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF										-
ST-MICROS M27	С				M	12706	4A									_										-
8Kx8		_	_	28	9	В	8					Verifie	es at:	5.00												_
For Help, press F1															Byt	e=0×0			BCRC=8F	995EA2	BSUM-	=3FBE 1065	Size=4M		EDIT	_
🛃 Start 🛛 👿	C	X (j 🙆) 🔍			77 I C	E Teo	hnolc	gy: '	#inL'	v	Do	cume	nt1 -	Microso	ft W]				[🗿 🌾 🔊 🔳 🖥	15	4:15 PM	1

Figure 13 - Device selection

The data has now been loaded into the ROM.

7. At the end of the operation the program data has been programmed into the ROM and it should also report that the data was verified as shown below in Figure 14.

7 ICE Teo	chnola	ogy: W	inL¥∙	- M27	7C64	A - [U	Intitl	ed]																				_ 8	×
File Edit	View	Progr	amme	er He	elp																								
0 🖻		3 E	3 4	3 🛾		(B		8		I 🐳	4		்	☆ x	žž	# 4	滿	14 <u>*</u> *}+	***	000	XXX B1	EX XXXX BOB1							
Byte	e	00	01	02	03	04	05	06	07	08	09	0A	0B	00	OD	0E	OF	01	23456	57892	ABCD	EF							F
000000	000	00	00	02	02	04	04	06	06	08	08	0A	ΟA	05	05	07	07												Ξ
000000	010	01	01	03	03	05	05	06	06	00	00	02	02	OC	0C	0E	0E												
000000	020	07	07	07	07	07	06	06	06	06	06	03	03	03	03	03	05					••							
000000	030	05	05	05	05	01	01	01	01	01	04	04	04	04	04	04	04		• • • • •	• • • •	• • • •	••							
000000	040	07	07	07	07	07	06	06	06	06	06	04	04	04	04	04	00					••	1						
000000	050	00	00	l Up	erati	ions I	or de	evice	: M2	<i>1</i> Lb4	A																		
000000	080	01	01		oerati	on		_	AF I	= -	. 013		_	2	_	-0 [<u>`</u>		-						
000000	020	02	02	ì		-	3.B	-		*	* ?	•	-	₩.		×		P:F=1:0 (100%)	8	?	Close							
000000	090	00	03	ì																									
000000	0A0	05	01	i –																									
000000	0B0	00	00	(
000000	0C0	01	01	(Progr	amme	d and	Verifi	ed												
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000000	0E0	01	03									0070			40-1		1 - 5	0.00- T. (-1						
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000000	100	04	04	06	06	07	07	OF	OF	OE	OE	OE	OF	OF	OB	OF	06		• • • • •	• • • •	• • • •	••							
00000	120	05	UL	UL	UĽ OA	Uľ	UB	UF	UL	UL	UL	UF OF	OF	Uľ	10	Uľ	UF OG				• • • •	••							
00000	130	04	0A 04	DA DA	07	05	0D DF	017	0r 06	06	UE OF	06	0r	017	03	03	00					••							
00000	140	07 OE	DE	00	06	07	01	07	00	00	06	05	06	06	07	00	00 NF												
00000	150	OF	OE	OE	OA	0A	OB	0B	OF	OF	OE	OE	04	04	05	05	05												
00000	160	00	00	01	03	02	04	00	05	01	00	00	01	05	04	02	03												
000000	170	07	07	06	06	07	05	04	00	01	07	00	00	00	00	00	00												
00000	180	04	06	06	07	07	17	16	16	16	16	1F	1F	1F	1E	1A	1A												
000000	190	OF	OF	07	07	06	06	06	07	05	05	07	07	07	07	07	07												
000003	1A0	1A	1A	1E	1F	1F	1F	1F	1E	1E	16	16	17	17	17	17	16		• • • • •	• • •		••							
000003	1B0	OE	OE	OE	OF	07	07	07	06	16	16	17	17	OF	OF	06	06		• • • • •	• • •	• • • •	••							
000000	100	UC	UE	UE	UF	UF	UD	UE	UE	UE	UF	11	11	1E	1E	112	115		• • • • •	• • • •	• • • •	••							
00000	120	11	11	1Ľ	1E	1A 07	1B 07	18	18	IA 02	IA 0.2	IA 07	IA 07	IA 00	IA 0.2	IA 02	1A			• • • •	• • • •	••							
00000	120	03	07	00	00	07	07	03	02	02	03	07	07	00	02	03	07				• • • •	· ·							
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For Help, pr							LI E	-								Byt	e=uxi	1			BCRC	=0F995EA	2 1850	JM=3FBE 1	005		d1-22	EDIT	
Start	W	B	X, 🕺	9 🙆				TIC	E Tee	chnol	ogy: '	WinL	ł	🖬 Do	cume	nt1 -	Micros	soft W								🔍 E 🕥 🍊 🛃	13	4:19 PI	М

Figure14 - Data verification

Conclusion

Teaching students real industrial hardware/software has been a challenging one, the step by step illustration of usage of these hardware/software with proper screenshots improves students learning. There has been good student feedback about usage of software simulation for digital courses. PSpice now knows as Cadence SPB, is leading electronic automation design software, a student version can be obtain form the company's website. The company also has a "university program" that allows educational institutions to buy full version of this software at extremely low price.

References

[1] "How ROM Works" <u>http://computer.howstuffworks.com/rom.htm</u>, 1998-2005 How Stuff Work .Inc. 2.

[2] "Microprocessor", EDN, Vol 49 Issue 25, p110, 2p 12/7/2004

[3] Kleitz, W., "Digital Electronics with VHDL", Chapter. 16 Semiconductors, Magnetic, and Optical Memory, Prentice Hall 2005.

[4] Manes, S., "The Weird New World of Hardware Fixes", PC World, Vol. 23 Issue pg 176, 1p, 1c.

[5] Schweber, B., "Mems Make a Nonvolatile-Memory Match", EDN, Vol.49 Issue 16 pg 20, 1/4p, 8/5/2004

[6] Tocci, R, N. Widmer, and G. L. Moss, "Digital Systems: Principles and Applications, 9/E, Chpt. 12 Memory Devices, Prentice Hall 2003

[7] "Orcad Capture", <u>http://www.orcad.com/orcadcapture.aspx</u>, Cadence Design Systems, Inc. 2004

[8] "Using tt2rom to Synthesize Truth Table in ROM". <u>http://engineering.dartmouth.edu/~Brian_W_Pogue/demos/tt2rom.pdf</u>, Spring 2002

[9] Ameen, M., Brown, R., Rashik R, Sundaran S., Zeeshan, M. "Programming Read Only Memory with Orcad", unpublished manual.

[10] Cook, N., "Electronics: A Complete Course, 2/E", Chapter. 27 Semiconductor Memory, Prentice Hall 2004.