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## ACORN TECHNICAL MANUAL

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## Introduction

The Acorn Visual Display Unit Controller Board connects to the Standard Acorn Computer Bus and contains a memory mapped character storage R.A.M. which is transparently written to or read from by the C.P.U.

An MC 6845 programmable controller I.C. provides all the synchronisation signals to drive a 625 line 50 fields per second V.D.U. together with read addresses for the character R.A.M. Characters are then fed to an SAA5050 character generator IC which produces the necessary dot patterns to create the characters to refresh the V.D.U.

The SAA5050 produces Teletext standard characters and has Red, Green and Blue drive outputs giving coloured characters or graphics.

The R.G.B. and sync outputs may be used to drive a colour encoder and modulator for a U.H.F. Television; also provided is a 1 volt/75 ohm composite sync and video output which can directly drive a Monochrome Monitor on which the different colours will appear as different scales of grey.

The V.D.U. controller P C B is supplied in kit form with a full set of I.C. sockets. It is easily assembled using a small soldering iron and useful hints on assembly may be found in the Acorn Micro-computer system 1 Technical Manual. The board operates from a single +5v supply from which it draws not more than 500 mA.

Also provided are listings for programs which set up the MC6845, display 25 instructions in hex on the V.D.U. (with double or treble byte instructions on a single line) and allow the drawing or graphics or characters on the V.D.U. These programs may be loaded and run using the Acorn system 1 Monitor. A new monitor R.O.M. will shortly be available for linking the V.D.U. and an ASC II keyboard to Acorns' 4K Fast BASIC.

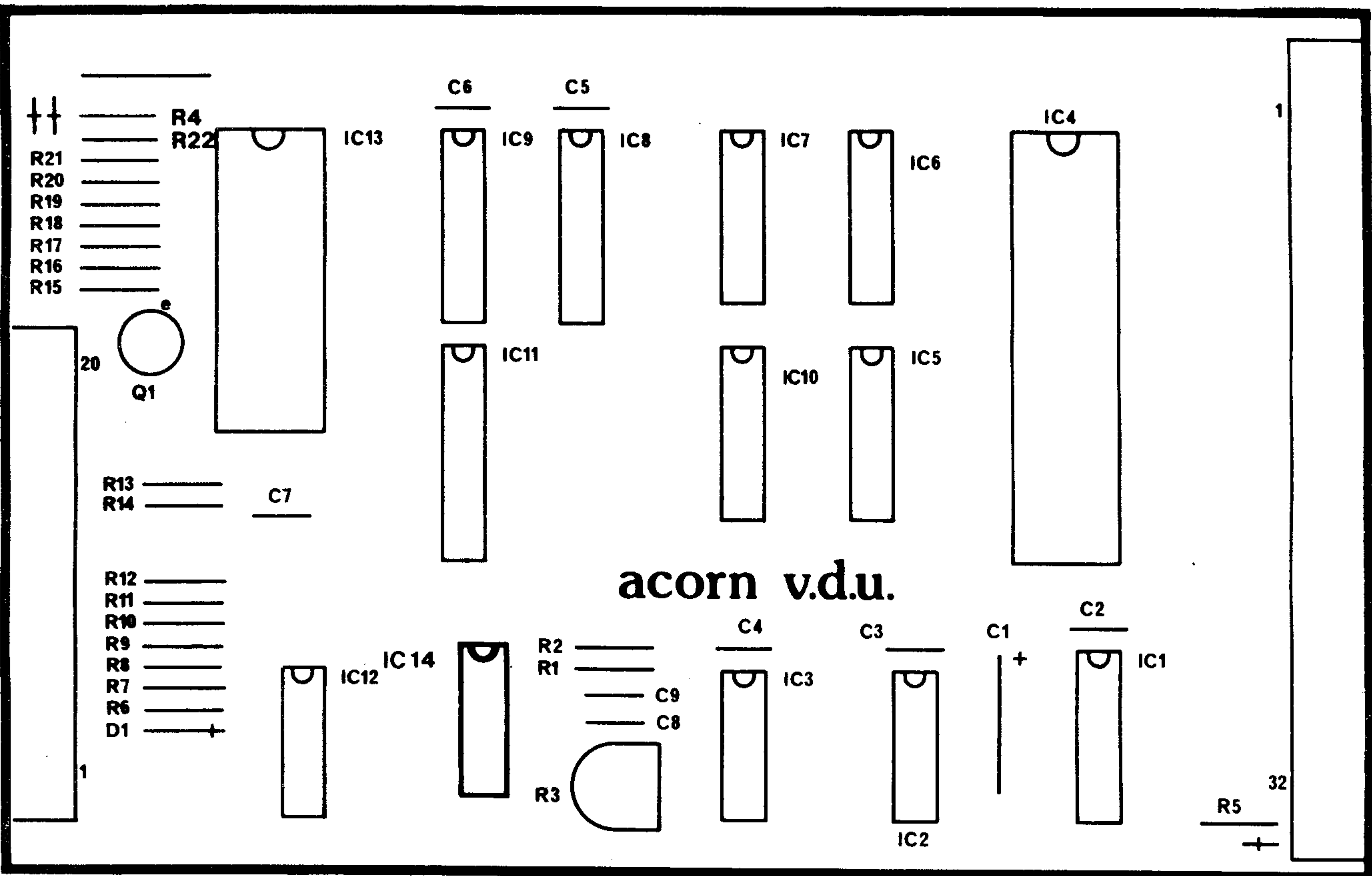
0360:	023F	E8	CBYTE	INX	INX		
0370:	0240	E8		LDYIM	\$00		
0380:	0241	A0 00	ABYTE	LDAIY	MOD		
0390:	0243	B1 00		JSR	SPBYTE		
0400:	0245	20 58 02		INC	MOD	increment the byte pointer	
0410:	0238	E6 00		BNE	NOINC		
0420:	024A	D0 02		INC	MOD	+01	
0430:	024C	E6 01	NOINC	DEX		print all bytes required	
0440:	024E	CA		BNE	ABYTE		
0450:	024F	D0 F0		DEC	COUNT		
0460:	0251	C6 0E		BPL	MAIN	finished the 25 lines?	
0470:	0253	10 B5		JMP	RESTR		
0480:	0255	4C 04 FF	GETOUT	PHA		print a space and then the byte	
0490:	0258	48	SPBYTE	LDAIM			
0500:	0259	A9 20		JSR	VDU		
0510:	025B	20 00 03		PLA			
0520:	025E	68		PHA			
0530:	025F	48	BYTOUT	LSRA		print a byte	
0540:	0260	4A		LSRA			
0550:	0261	4A		LSRA			
0560:	0262	4A		LSRA			
0570:	0263	4A		JSR	DIGOUT		
0580:	0264	20 68 02		PLA			
0590:	0267	68		ANDIM	\$0F	print the bottom Hex digit in A	
0600:	0268	29 0F	DIGOUT	ORAIM	\$30		
0610:	026A	09 30		CMPIM	\$3A		
0620:	026C	C9 3A		BCC	PUT		
0630:	026E	90 02		ADCIM	\$06		
0640:	0270	69 06		JMP	VDU		
0650:	0272	4C 00 03	PUT				

The VDU controller may reside in memory with the Keywriter, the Mini-Dissassembler or both and subsequently they may be stored on cassette tape in the usual way. User program space is then reduced to the range 0020 through 00FF with the page 0100 to 01FF used for stack space as before. The RAM in the INS 8154 IC's is also free to the user.

PARTS LIST FOR ACORN V.D.U. CONTROLLER

PCB	Acorn Computers Ltd. pt no 200,002
IC1	74LS139 decoder and 16 pin socket
IC2	74LS02 NOR gate and 14 pin socket
IC3	74LS13 schmitt trigger and 14 pin socket
IC4	MC6845 C.R.T. controller and 40 pin socket
IC5, 6 & 7	74LS157 data selector and 16 pin sockets
IC8 & 9	2114-3 R.A.M. and 18 pin sockets
IC10	74LS174 hex flip-flop and 16 pin socket
IC11	INS 8208 buffer and 20 pin socket
IC12	74LS86 excl or gate and 14 pin socket
IC13	SAA5050 character generator and 28 pin socket
IC14	74LS00 NAND gate and 14 pin socket
Q1	BC107 transistor
D1	1N4148 diode
R1	1K resistor
R2	2K7 resistor
R3	470 R preset potentiometer
R4	10K resistor
R5	4K7 resistor not supplied with kit
R6	22K resistor
R7	4K7 resistor
R8	10K resistor
R9-12	4 off 10K resistors
R13	4K7 resistor
R14	10K resistor
R15	470R resistor
R16	82R resistor
R17	18K resistor not supplied with kit
R18	10K resistor
R19	10K resistor not supplied with kit
R20-22	3 off 10K resistors
C1	10 or 15 uF electrolytic capacitor
C2-7	6 off 47 nF capacitors
C8	270pF capacitor
C9	150pF capacitor

NB For IC11 INS8208 is equivalent to DP8304



200.002 Iss.1

Acorn Minidissassembler

The minidissassembler provides a formatted listing of 25 lines of 6502 program instructions in machine code presented in Hexadecimal.

The start address of the program to be disassembled is entered into the m address of the Acorn Monitor using the m key and the dis-assembler program is then executed from 0200 using the g key in the normal way. A formatted 25 lines of instructions will be displayed on the screen and the program ends in a jump back to the monitor. The m address is stepped forwards so re-running the program will display the next 25 program lines.

MINDIS	ACORN 6502 Assembler	ORG		
0010:	0200	MINDIS	*	\$0200
0020:	0200	MOD	*	\$0000
0030:	0200	COUNT	*	\$000E
0040:	0200	VDU	*	\$0300
0050:	0200	RESTR	*	\$FF04
0060:	0200	START		
0070:	0202	STA		
0080:	0204	CLD		
0090:	0205	LDAIM	\$0C	disassemble 25 lines
0100:	0207	JSR	VDU	start with a form-feed
0110:	020A	LDAIM	\$0D	carriage return/line feed for each line
0120:	020C	JSR	VDU	
0130:	020F	LDAIM	\$0A	
0140:	0211	JSR	VDU	
0150:	0214	LDA	MOD	+01 display current address
0160:	0216	JSR	\$PBYTE	
0170:	0219	LDA	MOD	
0180:	021B	JSR	BYTOUT	
0190:	021E	LDYIM	\$00	
0200:	0220	LDXIM	\$01	X will be the byte count of the opcode
0210:	0222	LDAIY	MOD	fetch opcode, find it's no. of bytes
0220:	0224	CMPIM	\$20	'jsr' is an anomaly and is done first
0230:	0226	BEQ	CBYTE	
0240:	0228	ANDIM	\$9F	
0250:	022A	BEQ	ABYTE	binary 0XX00000 is 1 byte
0260:	022C	ANDIM	\$1D	
0270:	022E	CMPIM	\$19	
0280:	0230	BEQ	CBYTE	binary XXX110X1 is 3 bytes
0290:	0232	ANDIM	\$0D	
0300:	0234	CMPIM	\$08	
0310:	0236	BEQ	ABYTE	binary XXXXXX0X0 (now) is 1 byte
0320:	0238	ANDIM	\$0C	
0330:	023A	CMPIM	\$0C	
0340:	023C	BEQ	CBYTE	binary XXXX11XX is 3 bytes
0350:	023E	DEX		all others are 2 bytes

## Acorn Keywrite

The keywrite program is entered at MAIN (0280). When this program is first used after switching on a form feed can be sent to the screen to program the 6845 by pressing the 'r' key.

The program then accepts pairs of Hex characters before sending them to the screen, by-passing the control interpreter to allow any code to be sent. The control keys provide the following functions

1	Line feed	g	space
Λ	delete	p	space
V	carriage return	s	space
r	form feed	m	return to monitor

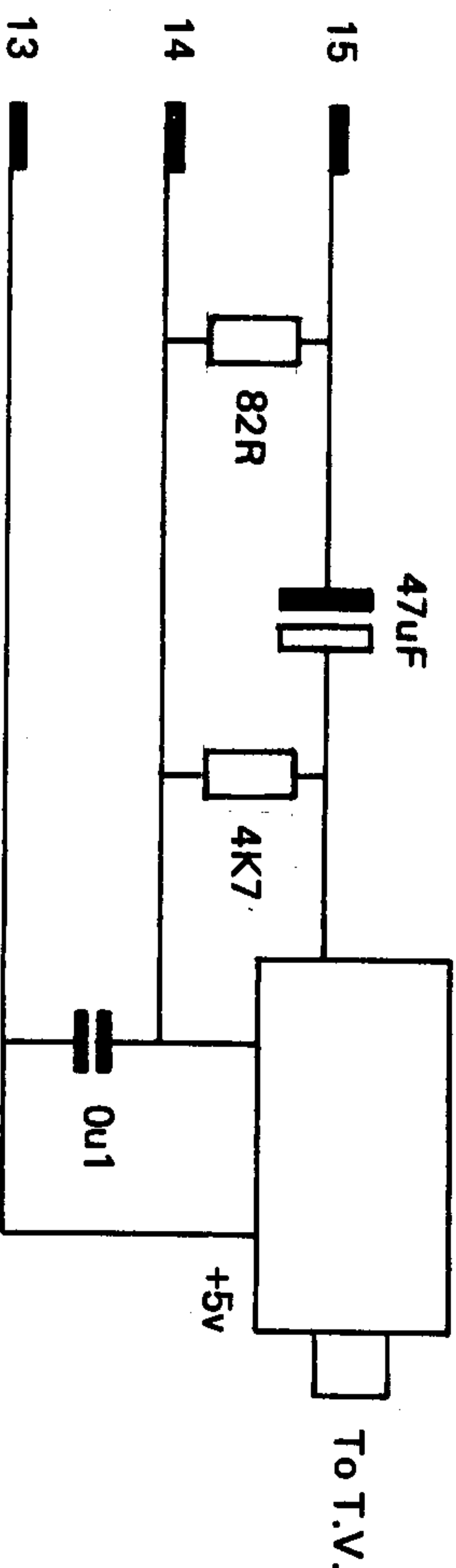
KEYWRT	ACORN 6502 Assembler	KEYWRT	ORG	
0010:	0280	KEYWRT	0280	
0020:	0280	TEMP	\$0026	
0030:	0280	RESTRT	\$\$\$F04	
0040:	0280	DISPLA	\$\$\$F0C	
0050:	0280	VDU	\$0300	
0060:	0280	20 0C FE MAIN	DISPLA	
0070:	0283	90 0E	SEND	hex key ?
0080:	0285	29 07	CONTRL	
0090:	0287	F0 18	ANDIM	\$07
0100:	0289	A8	BEQ	RETURN
0110:	028A	B9 A6 02	TAY	
0120:	028D	20 00 03	LDAAY	TABLE
0130:	0290	4C 80 02	JSR	VDU
0140:	0293	0A	JMP	MAIN
0150:	0294	0A	ASLA	
0160:	0295	0A	ASLA	
0170:	0296	0A	ASLA	
0180:	0297	85 26	STA	TEMP
0190:	0299	20 0C FE	JSR	DISPLA
0200:	029C	B0 E7	BCS	CONTRL
0210:	029E	05 26	ORA	TEMP
0220:	02A0	09 80	ORAIM	mix in low digit
0230:	02A2	30 E9	BMI	fool control character check
0240:	02A4	4C 0A FF	JMP	SENDER forced branch to sender
0250:	02A7	20	TABLE	RESTRT M key returns to monitor
0260:	02A8	20		G key gives space bar
0270:	02A9	20		P key gives space bar
0280:	02AA	0A		S key gives space bar
0290:	02AB	0C		L key gives line-feed
0300:	02AC	7F		R key gives form-feed
0310:	02AD	0D		\\ key gives delete
				// key gives carriage return

look up control keys in table  
-01

## Applications

To use this board in the Acorn system a low for block zero signal must be present on pin 31A of the Acorn bus. This is provided by connecting pin 8 of IC9 to pin 31A of the connector on the 6502 C.P.U. board. The 5 volt regulator and the electrolytic capacitor must be removed from the C.P.U. board and an external 5 volt supply at 3 amps is required on pin 1A of all boards for a system using the C.P.U., V.D.U. interface, 8K memory board and cassette interface.

A 1 volt at 75 ohm video monitor may be driven directly from connections 14 and 15 on the front of the board. Alternatively a UHF modulator may be driven which connects to the aerial input of a domestic television set using the circuit shown



the component values given suit the Astec UM 1233E36 modulator although other types should work satisfactorily.

IC3 on the VDU board forms a 6MHz dot clock which is adjusted using the preset resistor R3 to give characters of the right width on a steady picture after MC6845 has been initialised using the Applications programmes.

The 1024 byte character memory appears in block zero of the Acorn address map filling pages 04, 05 06 and 07. Two registers, which set up the 6845, are at addresses 0800 and 0801 and these repeat throughout page 08. The register at 0800 is a 5 bit write only register used to determine which of the data registers is accessed at 0801. The data registers, their addresses and their functions are tabulated here.

Register Address	Function	Program Unit	Type	No of Bits Used
00	Horizontal total	char	Write only	8
01	Horizontal displayed	"	"	8
02	H Sync Position	"	"	8
03	H Sync Width	"	"	4
04	Vertical total	char row	"	7
05	V total adjust	scan line	"	5
06	Vertical displayed	char row	"	7
07	V sync position	char row	"	7
08	Interface mode	—	"	2
09	Max scan line address	scan line	"	5
0A	Cursor start	scan line	"	5 + 2
0B	Cursor end	scan line	"	5
0C	Start address H	—	"	6
0D	Start address L	—	"	6
0E	Cursor H	—	Read/Write	6
0F	Cursor L	—	Read/Write	8
10	Light pen H	—	Read only	6
11	Light pen L	—	Read only	8

Using the programs provided all these registers are initialised for 625 line, 50 fields per second, non-interlaced operation with 25 rows each of 40 characters.

Hardware scrolling is used in the system which, with transparent access, gives a clean display and uses only a very small proportion of C.P.U's time. The character memory may be read from or written to at any time like any other piece of R.A.M.

The light pen input to the board may be used after breaking the link to 0v and fitting a 4K7 resistor for R5. When the light pen input goes high the contents of the character refresh address counter are strobed into registers 10 and 11 i.e. high byte and low byte. Thus the screen co-ordinates of the pen position may be determined.

The SAA 5050 character generator produces the following characters represented by the hexbytes shown.

1270:	03DF	19	=	\$19	25	displayed	character	rows
1280:	03E0	1B	=	\$1B		position of vertical sync pulse		
1290:	03E1	00	=	\$00		set non-interlace mode		
1300:	03E2	09	=	\$09		set 10 lines per character row		
1310:	03E3	68	=	\$68		slow blink cursor from line 9		
1320:	03E4	09	=	\$09		to line 10		
1330:	03E5	04	=	\$04		high address of VDU ram		
1340:	03E6	00	=	\$00		low address of VDU ram		
1350:	03E7	07	=	\$07		high address of initial cursor position		
1360:	03E8	C0	=	\$C0		low address of initial cursor position		

Two further programs may be loaded which employ the V.D.U. control subroutine.

0740:	0383	A0 28	LDYIM	\$28	
0750:	0385	20 B5 03	JSR	CALCN	
0760:	0388	A5 23	LDA	WORK	
0770:	038A	85 21	STA	LINE	
0780:	038C	A5 25	LDA	WORK	+02
0790:	038E	85 22	STA	LINE	+01
0800:	0390	A0 0D	LDYIM	\$0D	
0810:	0392	8C 00 08	STY	CRTA	
0820:	0395	A5 21	LDA	LINE	
0830:	0397	38	SEC		
0840:	0398	E9 C0	SBCIM	\$C0	
0850:	039A	8D 01 08	STA	CRTB	
0860:	039D	88	DEY		
0870:	039E	8C 00 08	STY	CRTA	
0880:	03A1	A5 25	LDA	WORK	+02
0890:	03A3	E9 03	SBCIM	\$03	
0900:	03A5	8D 01 08	STA	CRTB	
0910:	03A8	A0 27	LDYIM	\$27	
0920:	03AA	A9 20	LDAIM		
0930:	03AC	20 CD	JSR	WRCH	
0940:	03AF	88	DEY		
0950:	03B0	10 FA	BPL	CLEARL	
0960:	03B2	68	PLA		
0970:	03B3	28	PLP		
0980:	03B4	60	RTS		
0990:	03B5	08	PHP		
1000:	03B6	48	PHA		
1010:	03B7	D8	CLD		
1020:	03B8	18	CLC		
1030:	03B9	98	TYA		
1040:	03BA	65 21	ADC	LINE	
1050:	03BC	85 23	STA	WORK	
1060:	03BE	A5 22	LDA	LINE	+01
1070:	03C0	69 00	ADCIM	\$00	
1080:	03C2	85 25	STA	WORK	+02
1090:	03C4	29 07	ANDIM	\$07	
1100:	03C6	09 04	ORAIM	\$04	
1110:	03C8	85 24	STA	WORK	+01
1120:	03CA	68	PLA		
1130:	03CB	28	PLP		
1140:	03CC	60	RTS		
1150:	03CD	20 B5 03	JSR	CALCN	
1160:	03D0	84 25	STY	WORK	+02
1170:	03D2	A0 00	LDYIM	\$00	
1180:	03D4	91 23	STAIY	WORK	
1190:	03D6	A4 25	LDY	WORK	+02
1200:	03D8	60	RTS		
1210:	03D9	3F			
1220:	03DA	28			
1230:	03DB	33			
1240:	03DC	05			
1250:	03DD	1E			
1260:	03DE	02			

do calculation to make sure that the processor and crt controller agree on position of screen

total number of characters per line  
40 characters displayed  
position of horizontal sync  
width in US of horizontal sync pulse  
total number of character rows  
additional no. of lines for 312 total

20	space	30	0	40	@	50	P	60	-	70	p
21	!	31	1	41	A	51	Q	61	a	71	q
22	"	32	2	42	B	52	R	62	b	72	r
23	£	33	3	43	C	53	S	63	c	73	s
24	\$	34	4	44	D	54	T	64	d	74	t
25	%	35	5	45	E	55	U	65	e	75	u
26	&	36	6	46	F	56	V	66	f	76	v
27	'	37	7	47	G	57	W	67	g	77	w
28	(	38	8	48	H	58	X	68	h	78	x
29	)	39	9	49	I	59	Y	69	i	79	y
2A	*	3A	:	4A	J	5A	Z	6A	j	7A	z
2B	+	3B	;	4B	K	5B	←	6B	k	7B	¼
2C	,	3C	<	4C	L	5C	½	6C	l	7C	½
2D	-	3D	=	4D	M	5D	→	6D	m	7D	¾
2E	.	3E	>	4E	N	5E	↑	6E	n	7E	÷
2F	/	3F	?	4F	O	5F	≠	6F	o	7F	delete

Note that there are a few exceptions to the usual ASCII, the most noticeable of which is at 23 where £ replaces ¢ which is moved from 23 to 5F.

Also available are the following teletext control characters with their hexadecimal codes shown:--

01	Alpha	Red	11	Graphics	Red
02	"	Green	12	"	Green
03	"	Yellow	13	"	Yellow
04	"	Blue	14	"	Blue
05	"	Magenta	15	"	Magenta
06	"	Cyan	16	"	Cyan
07	"	White	17	"	White
08	Flash		18	Conceal Display	
09	Steady		19	Contiguous Graphics	
0A	End Box		1A	Separated Graphics	
0B	Start Box				
0C	Normal Height		1C	Black Background	
0D	Double Height		1D	New Background	
			1E	Hold Graphics	
			1F	Release Graphics	

These characters affect the characters displayed to the right of them on a line, and provide the following options:—

**ALPHA (COLOUR)** causes following characters on the line to be in the colour specified.

**GRAPHICS (COLOUR)**

In Graphics mode each character space displayed is divided into 6 cells. Each cell is illuminated, in the specified colour, if a corresponding bit in the ASCII code stored at that location is set. The bit assignments are:—

b <sub>0</sub>	b <sub>1</sub>
b <sub>2</sub>	b <sub>3</sub>
b <sub>4</sub>	b <sub>6</sub>

Bit 5 in the byte is always set for a graphics character, if bit 5 is clear then the upper case, alphabet and characters ←, ½, →, ↑, ≠, @ are available in the same colour.

**FLASH** causes the following characters on the line to flash.

**STEADY** terminates the flash option on a line.

**END BOX & START BOX** Are options for using the circuit to superimpose text onto a normal TV picture.

**DOUBLE HEIGHT** Must appear on two consecutive lines followed by the same characters in which case the characters fill the two lines specified.

**NORMAL HEIGHT** Clears the double height option on a line.

0210:	0315	A0 00	VDUA	LDYIM	\$00	
0220:	0317	20 85	VDUB	JSR	CALCN	
0230:	031A	84 20		STY	SCAP	
0240:	031C	A0 0F		LDYIM	\$0F	rewrite cursor position
0250:	031E	8C 00	08	STY	CRTA	
0260:	0321	A4 23		LDY	WORK	
0270:	0323	8C 01	08	STY	CRTB	
0280:	0326	A0 0E		LDYIM	\$0E	
0290:	0328	8C 00	08	STY	CRTA	
0300:	032B	A4 25		LDY	WORK	+02
0310:	032D	8C 01	08	STY	CRTB	
0320:	0330	60		RTS		
0330:	0331	88		DEY		
0340:	0332	30 FC		BMI	VDUC	refuse to delete before line start
0350:	0334	A9 20		LDAIM		write in a blank
0360:	0336	20 CD	03	JSR	WRCH	
0370:	0339	A9 7F		LDAIM	\$7F	
0380:	033B	D0 DA		BNE	VDUB	
0390:	033D	C9 0D		CMPIM	\$0D	carriage return?
0400:	033F	F0 D4		BEO	VDUA	line feed?
0410:	0341	C9 0A		CMPIM	\$0A	
0420:	0343	F0 06		BEO	SCROL	
0430:	0345	C9 0C		CMPIM	\$0C	form feed?
0440:	0347	F0 09		BEO	CLEAR	
0450:	0349	D0 BF		BNE	TOSCRN	
0460:	034B	20 80	03	JSR	SCROLL	scroll screen and rewrite cursor
0470:	034E	A4 20		LDY	SCAP	
0480:	0350	B0 C5		BCS	VDUB	
0490:	0352	48		PHA		
0500:	0353	A0 00		LDYIM	\$00	clear entire buffer
0510:	0355	A9 20		LDAIM		
0520:	0357	99 00	04	STAY	SCRA	
0530:	035A	99 00	05	STAY	SCRB	
0540:	035D	99 00	06	STAY	SCRC	
0550:	0360	99 00	07	STAY	SCRD	
0560:	0363	C8		INY		
0570:	0364	D0 F1		BNE	CLEAR	
0580:	0366	84 20		STY	SCAP	
0590:	0368	A0 0F		LDYIM	\$0F	
0600:	036A	8C 00	08	STY	CRTA	
0610:	036D	B9 D9	03	LDAA	CRTTAB	set up all the crt parameters
0620:	0370	8D 01	08	STA	CRTB	
0630:	0373	88		DEY		
0640:	0374	10 F4		BPL	SETCRT	
0650:	0376	A9 C0		LDAIM	\$C0	
0660:	0378	85 21		STA	LINE	
0670:	037A	A9 07		LDAIM	\$07	
0680:	037C	85 22		STA	LINE	+01
0690:	037E	68		PLA		
0700:	037F	60		RTS		
0710:	0380	08		PHP		
0720:	0381	48		PHA		
0730:	0382	D8		CLD		

scroll subroutine



Application Programs

VDU Controller

The program listed below may be loaded using the Acorn system 1 monitor starting at address 0300. This program is intended to be used as a subroutine by other programs and will take the contents of the accumulator and display the corresponding ASCII character on the screen at the current cursor position on being jumped to (JSR) at 0300. Before returning this subroutine will advance the cursor position and if the current line is full it will scroll the screen. Four control codes in the accumulator are intercepted by the program and produce the following action.

- OA ... Line feed
- OC ... Form feed i.e. clear screen and home cursor
- OD ... carriage return
- 7F ... back space cursor and delete character

The code OC must always be used after switch on to initialise the 6845 controller IC, clear the character RAM and home the cursor.

If the SAA5050 characters generated by the codes OA, OC, OD and 7F are required on the screen the same characters may be produced using the codes 8A, 8C, 8D and FF which the subroutine does not intercept.

VDU	ACORN 6502 Assembler	VDU	ORG	
0010:	0300	VDU	\$0300	
0020:	0300	SCAP	\$0020	
0030:	0300	LINE		+01
0040:	0300	WORK		+02
0050:	0300	SCRA	\$0400	memory addresses for the screen
0060:	0300	SCRB	\$0500	
0070:	0300	SCRC	\$0600	
0080:	0300	SCRD	\$0700	
0090:	0300	CRTA	\$0800	6845/6545 crt controller
0100:	0300	CRTB	\$0801	
0110:	0300	A4 20		LDY
		CHATS		SCAP
0120:	0302	C9 20		CMPIM
				\$20
0130:	0304	90 37		BCC
				CTL
0140:	0306	C9 7F		CMPIM
				\$7F
0150:	0308	F0 27		BEO
				DELETE
0160:	030A	20 CD 03		JSR
				TOSCRN
0170:	030D	C8		INY
0180:	030E	C0 28		CPYIM
				\$28
0190:	0310	90 05		BCC
				VDUB
0200:	0312	20 80 03		SCRLL
				FILLED
				JSR
				automatic scroll when line filled

CONCEAL DISPLAY

Switches off the character on a line these can only be revealed by applying a signal to the character generator chip (or deleting the CONCEAL character).

CONTIGUOUS GRAPHICS

In this mode the graphics cells in a character are joined up.

SEPARATED GRAPHICS

In this mode the graphics cells are separated by one character bit width.

NEW BACKGROUND

Sets the background to the colour of the last colour specifying character.

BLACK BACKGROUND

Resets the background colour to black.

HOLD GRAPHICS

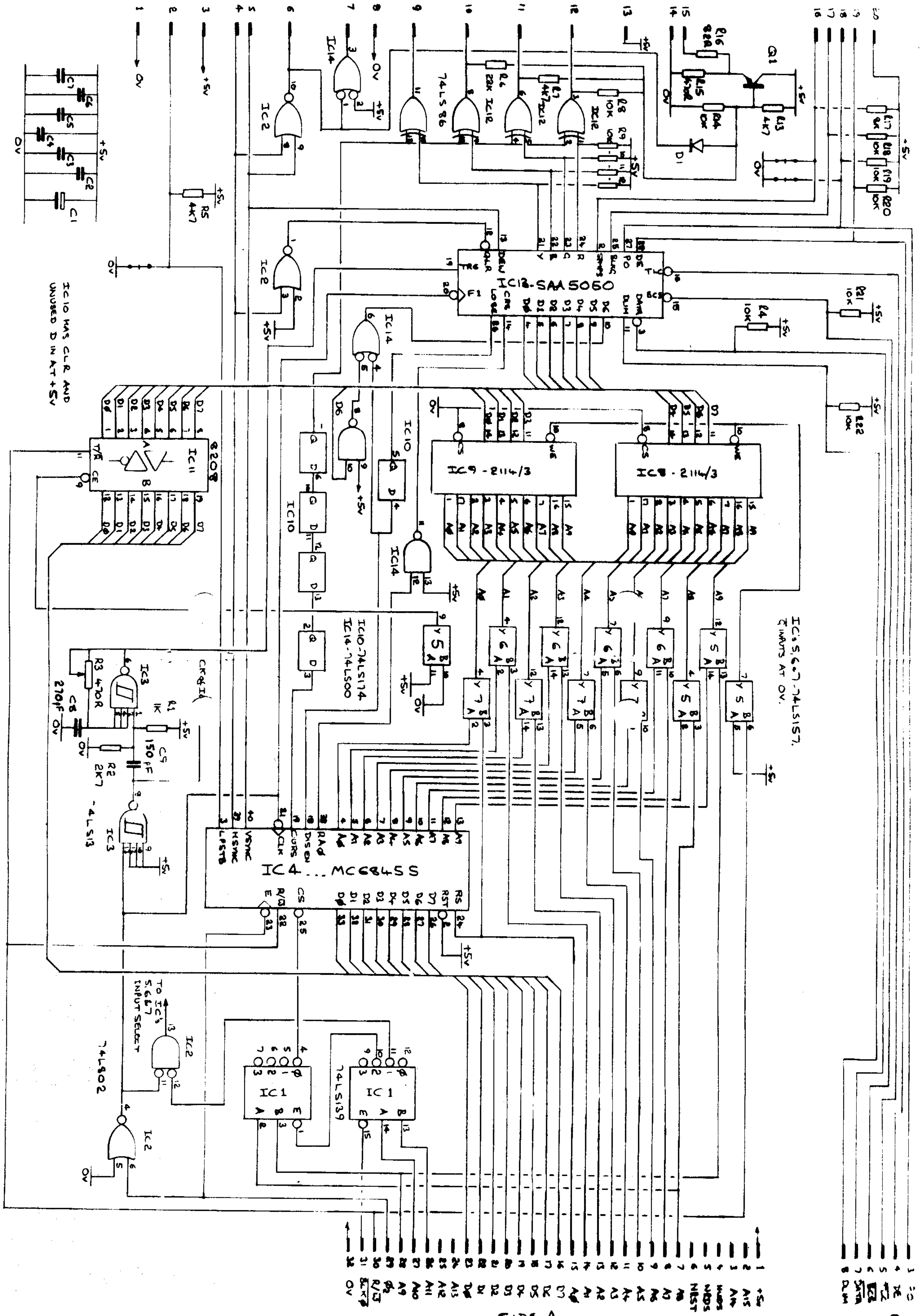
Causes the last graphics character to be displayed when a control character is entered.

RELEASE GRAPHICS

Causes a space (Background colour) to be displayed when a control character is entered.

The character generator assumes an initial setting at the start of each line of:--

ALPHA WHITE, STEADY, END BOX, NORMAL HEIGHT.  
CONTIGUOUS GRAPHICS, BLACK BACKGROUND, RELEASE GRAPHICS.



IC10 HAS CLR AND UNUSED D IN AT +5V

IC5,6,7 74LS157,  
TIMERS AT OV.

SIDE A

ISSUE	C	D	1
DATE	12/6/79	19/06/79	29/08/79
	CRT	CRT	CRT
DBN	CRT		
DATE	12/6/79		
TITLE	VDU INTERFACE PCB (TELETEXT).		
REF	200.002/C		
	Acorn Computers Ltd		