

## Appendix 3

# MC6847 data sheet

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### Advance Information

#### VIDEO DISPLAY GENERATOR (VDG)

The Motorola MC6847 Video Display Generator (VDG) provides a means of interfacing the Motorola M6800 microprocessor family (or similar products) to a commercially available color or black and white television receiver. Applications of the VDG include video games, bioengineering displays, education, communications and any place graphics are required.

The VDG reads data from memory and produces a composite video signal which will allow the generation of alphanumeric or graphic displays. The generated composite video may be up modulated to either Channel 3 or 4 by using the compatible MC1372 (TV Chroma and Video modulator). The up modulated signal is suitable for application to the antenna of a color TV. A typical TV game is indicated in Figure 1.

- Generates four different alphanumeric display modes and eight graphic display modes
- Compatible with the M6800 family
- Compatible with the MC1372 modulator
- The alphanumeric modes display 32 characters per line by 16 lines
- An internal multiplexer allows the use of either the internal ROM or an external character generator
- An external character generator can be used to extend the internal character set for "limited graphic" shapes
- A Mask Programmable internal character generator ROM is available on special order (Appendix A)
- One display mode offers 8-color 64 x 32 density graphics in an alphanumeric display mode
- One display mode offers 4-color 64 x 48 density graphics in an alphanumeric display mode
- All alphanumeric modes have a selectable video inverse
- Generates full video signal
- Generates R-Y and B-Y signals for external color modulator
- Full-graphic modes offer 64 x 64, 128 x 64, 128 x 96, 128 x 192, or 256 x 192 densities
- Full-graphic modes allow 2-color or 4-color data structures
- Full-graphic modes use one of two 4-color sets or one of two 2-color sets
- Available in either an interlace mode (NTSC Standard) or a non-interlace mode

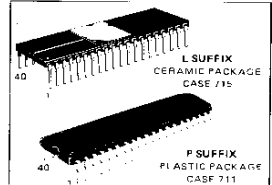
This is advance information and specifications are subject to change without notice.

313

**MC6847**  
NONINTERLACE  
**MC6847Y**  
INTERLACE

**MOS**  
(IN-CHANNEL, SILICON-GATE)

**VIDEO  
DISPLAY  
GENERATOR**



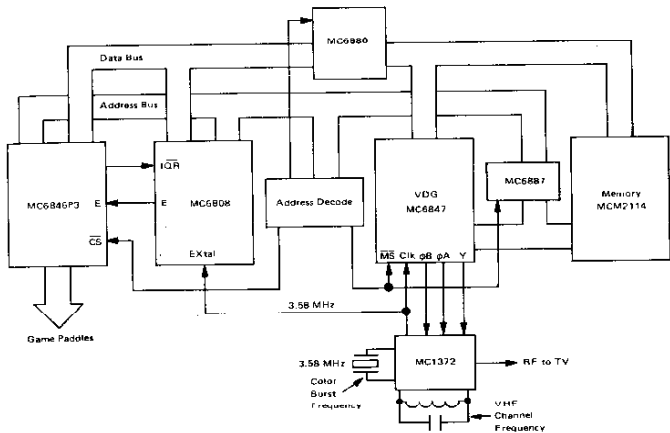
#### PIN ASSIGNMENT

1	VSS	DD7	40
2	DD8	CS5	39
3	DD0	FS	38
4	DD1	FS	37
5	DD2	FP	36
6	DD3	A/G	35
7	DD4	A/S	34
8	DD5	Clk	33
9	CH8	INV	32
10	DB	INT/EXT	31
11	CA	GM0	30
12	MS	GM1	29
13	DA5	Y	28
14	DA6	GM2	27
15	DA7	DA4	26
16	DA8	DA3	25
17	VCC	DA2	24
18	DA9	DA1	23
19	DA10	DA0	22
20	DA11	DA12	21

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FIGURE 1 - BLOCK DIAGRAM OF USE OF THE VDG IN A TV GAME



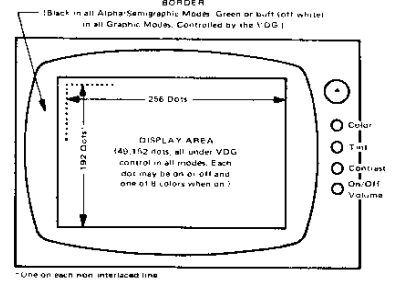
Mnemonic	Pin Numbers	Function
VCC	17	+5V
VSS	1	Ground
CLK	J3	Color burst clock 3.579545 MHz (input)
DA0-DA12	22, 23, 24, 25, 26, 13, 14, 15, 16, 18, 19, 20, 21	Address lines to display memory, high impedance during memory select ( $\overline{MS}$ )
DD0-DD5	3, 4, 5, 6, 7, 8	Data from display memory RAM or ROM
DD6, DD7	2, 40	Data from display memory in graphic mode; data also in alpha external mode; color data in alpha semigraphic 4 or 6
$\phi A, \phi B, Y$	11, 10, 28	Chrominance and luminance analog (R-Y, B-Y, Y) outputs to RF modulator (MC1372)
CHB	9	Chroma bias; reference $\phi A$ and $\phi B$ levels
RP	36	Row preset - Output to provide timing for external character generator.
HS	38	Horizontal Sync - Output to provide timing for external character generator.
INV	32	Inverts video in all alpha modes
INT/EXT	31	Switches to external ROM in alpha mode and between SEMIG-4 and SEMIG-6 in semigraphics
$\overline{A/S}$	34	Alpha/Semigraphics; selects between alpha and semigraphics in alpha mode
$\overline{MS}$	12	Memory select forces VDG address buffers to high-impedance state
$\overline{A/G}$	35	Switches between alpha and graphic modes
FS	37	Field Synchronization goes low at bottom of active display area.
CSS	39	Color set select; selects between two alpha display colors or between two color sets in semigraphics 6 and full graphics
GM0-GM2	30, 29, 27	Graphic mode select; select one of eight graphic modes.

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Rating	Value
Supply Voltage ( $V_{CC}$ )	-0.3 to +7.0V
Input Voltage any Pin	-0.3 to +7.0V
Operating Temperature	0°C to 70°C
Storage Temperature	-85°C to 150°C
Power Dissipation	TBD

FORMAT OF THE TELEVISION SCREEN



DC (STATIC) CHARACTERISTICS - ( $V_{CC} = 5.0V \pm 5\%$ ,  $V_{SS} = 0.0V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$  unless otherwise noted)

Characteristic	Symbol	Min	Typ.	Max.	Unit
Input High Voltage Clk Other Inputs	$V_{IH}$	$V_{CC} + 2.4$ $V_{SS} + 2.0$	-	$V_{CC}$ $V_{CC}$	Vdc
Input Low Voltage Clk Other Inputs	$V_{IL}$	$V_{SS} - 0.3$ $V_{SS} - 0.3$	-	$V_{SS} + 0.4$ $V_{SS} + 0.8$	Vdc
Input Leakage Current CLK, GM0-GM2, INV, INT/EXT, $\overline{MS}$ , VSS, DD0-DD7, A/S, A/G	$I_{in}$	-	-	2.5	$\mu A_{dc}$
Three-State (OH State) Input Current DA0-DA12	$I_{LO}$	-	-	10	$\mu A_{dc}$
Output High Voltage ( $I_{CLoad} = 30 \mu F, I_{Load} = -100 \mu A$ )	$V_{OH}$	2.4	-	-	Vdc
Output High Voltage ( $I_{CLoad} = 55 \mu F, I_{Load} = -100 \mu A$ )	DA0-DA12 $V_{OH}$	2.4	-	-	Vdc
Output Load Voltage ( $I_{CLoad} = 30 \mu F, I_{Load} = 1.6 mA$ )	RP, HS, FR $V_{OL}$	-	-	$V_{SS} + 0.4$	Vdc
Output Load Voltage ( $I_{CLoad} = 55 \mu F, I_{Load} = 1.6 mA$ )	DA0-DA12 $V_{OL}$	-	-	$V_{SS} + 0.4$	Vdc
Output High Current (Sourcing) ( $V_{OH} = 2.4 V$ )	All Outputs (except $\phi A, \phi B, Y, \& CHB$ ) $I_{OH}$	-100	-	-	$\mu A_{dc}$
Output Low Current (Sinking) ( $V_{OL} = 0.4 Vdc$ )	All Outputs (except $\phi A, \phi B, Y, \& CHB$ ) $I_{OL}$	1.6	-	-	$\mu A_{dc}$
Input Capacitance ( $V_{in} = 0, T_A = 25^\circ C, f = 1.0 MHz$ )	All Inputs $C_{in}$	-	-	7.5	pF
Chroma Bias Voltage ( $I_{CLoad} = 20 \mu F, R_{Load} = 200 k \Omega, V_{CC} = 4.75 - 5.25 V$ )	$V_R$	-	0.3 $V_{CC}$	-	Vdc

DC (STATIC) CHARACTERISTICS -  $V_{CC} = 5.0 V \pm 5\%$ ,  $V_{SS} = 0.0 V$ ,  $T_A = 0^\circ C$  to  $70^\circ C$  unless otherwise noted

Characteristic	Symbol	Min	Typ.	Max.	Unit
Chroma (A) Voltage (C <sub>Load</sub> = 20 pF, R <sub>Load</sub> = 200 k ohm)	V <sub>CoA</sub> V <sub>H</sub> V <sub>O</sub> V <sub>LO</sub>	-	V <sub>R</sub> + 0.1 V <sub>CC</sub> V <sub>R</sub> V <sub>R</sub> - 0.1 V <sub>CC</sub>	-	V <sub>dc</sub>
Chroma (B) Voltage (C <sub>Load</sub> = 20 pF, R <sub>Load</sub> = 200 k ohm)	V <sub>CoB</sub> V <sub>O</sub> V <sub>Burst</sub> V <sub>LO</sub>	-	V <sub>R</sub> + 0.1 V <sub>CC</sub> V <sub>R</sub> V <sub>R</sub> - 0.05 V <sub>CC</sub> V <sub>B</sub> - 0.1 V <sub>CC</sub>	-	V <sub>dc</sub>
Luminance Y Voltage (C <sub>Load</sub> = 20 pF, R <sub>Load</sub> = 200 k ohm)	V <sub>Y</sub> V <sub>S</sub> V <sub>BLANK</sub> V <sub>BLACK</sub>	-	0.2 V <sub>CC</sub> 0.75 V <sub>S</sub> 0.7 V <sub>S</sub>	-	V <sub>dc</sub>
Voltage White Low (Voltage White Medium) (Voltage White High)	V <sub>WL</sub> V <sub>WM</sub> V <sub>WH</sub>	-	0.62 V <sub>S</sub> 0.5 V <sub>S</sub> 0.98 V <sub>S</sub>	-	V <sub>dc</sub>

AC (Dynamic) CHARACTERISTICS -  $V_{CC} = 5.0 V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$

Characteristic	Symbol	Min	Typ.	Max.	Unit
Clk Frequency Clk Duty Cycle	f Clk <sub>dc</sub>	3.579535 45%	3.579545 50%	3.579565 55%	MHz
Chroma Phase Delay (Measured with respect to "Y" output)	φ <sub>A</sub> φ <sub>B</sub>	-	200 200	-	ns
Luminance Rise Time Luminance Fall Time	t <sub>ry</sub> t <sub>fy</sub>	-	60 50	-	ns
Chroma Rise and Fall Times (φ <sub>A</sub> Rise Time) (φ <sub>A</sub> Fall Time) (φ <sub>B</sub> Rise Time) (φ <sub>B</sub> Fall Time)	t <sub>rCoA</sub> t <sub>fCoA</sub> t <sub>rCoB</sub> t <sub>fCoB</sub>	-	60 60 60 60	-	ns
Field Sync. (FS) (Pulse Width)	t <sub>WFS</sub>	-	2.03	-	ms
Row Preset (RP) (Pulse Width) (Delay From HS)	t <sub>WRP</sub> t <sub>NSRP</sub>	-	0.98 0.98	-	μs
Horizontal Sync (HS)	t <sub>WHS}</sub>	-	4.9	-	μs

FIGURE 2 - VIDEO AND CHROMINANCE RELATIONSHIPS OUTPUT WAVEFORM

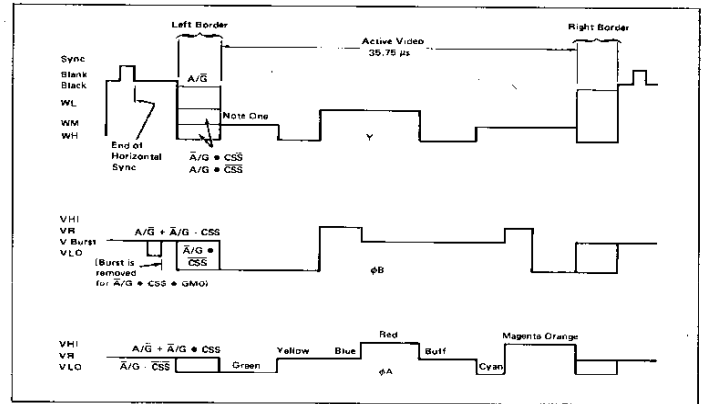
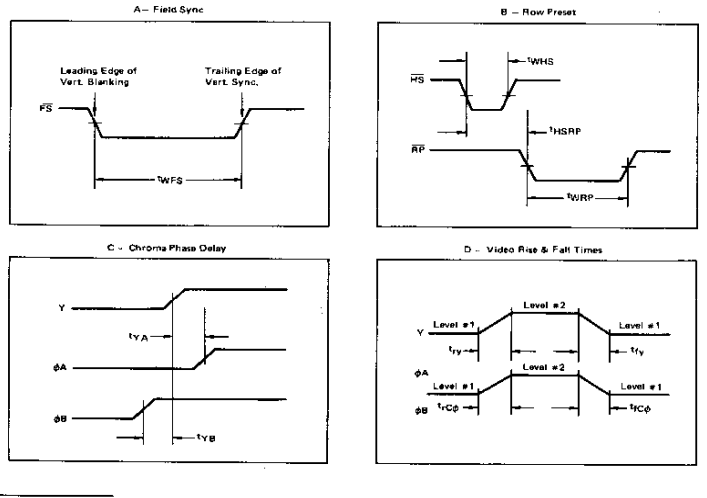


FIGURE 3 - TIMING DIAGRAMS



## VDG SIGNAL DESCRIPTION

**Address Output Lines (DA0-DA12)** — Thirteen address lines are used by the VDG to scan the display memory. The starting address of the display memory is located at the upper left corner of the display screen. As the television sweeps from the left to right and top to bottom, the VDG increments the RAM display address. These lines are TTL compatible and may be forced into a high impedance state whenever the  $\overline{MS}$  pin goes low.

**Data Inputs (DD0-DD7)** — Eight TTL compatible data lines are used to input data from RAM to be processed by the VDG. The data is interpreted and transformed into luminance Y (Pin 28) and color outputs  $\phi A$  and  $\phi B$  (Pin 11 and Pin 10).

**Power Inputs** —  $V_{CC}$  requires +5 volts.  $V_{SS}$  requires zero volts and is normally ground. The tolerance and current requirements of the VDG are specified in the Electrical Characteristics.

**Video Outputs ( $\phi A$ ,  $\phi B$ , Y, CHB)** — These four analog outputs are used to transfer luminance and color information to a standard NTSC color television receiver, either via the MC1372 RF modulator or directly into Y,  $\phi A$ ,  $\phi B$  television video inputs.

**LUMINANCE (Y)** — This six level analog output contains composite sync, blanking and four levels of video luminance.

$\phi A$  — This three level analog output is used in combination with  $\phi B$  and Y outputs to specify one of eight colors.

$\phi B$  — This four level analog output is used in combination with  $\phi A$  and Y outputs to specify one of eight colors. Additionally, one analog level is used to specify the time of the color burst reference signal.

**CHROMA BIAS (CHB)** — This pin is an analog output and provides a D.C. reference corresponding to the quiescent value of  $\phi A$  and  $\phi B$ . CHB is used to guarantee good thermal tracking and minimize the variation between the parts.

**Synchronizing Inputs ( $\overline{MS}$ , CLK)**

**Three-State Control** — ( $\overline{MS}$ ) is a TTL compatible input which, when low, forces the VDG address lines into a high impedance state. This may be done to allow other devices (such as an MPU) to address the display memory (RAM).

**Clock (CLK)** — The VDG clock input (CLK) requires a 3.579545 MHz (standard) TV crystal frequency square wave. The duty cycle of this clock must be between 45

and 55 percent since it controls the width of alternate dots on the television screen. The MC1372 RF modulator may be used to supply the 3.579545 MHz clock and has provisions for a duty cycle adjustment.

**Synchronizing Outputs ( $\overline{FS}$ ,  $\overline{HS}$ ,  $\overline{RP}$ )** — Three TTL compatible outputs provide circuits, exterior to the VDG, with timing references to the following internal VDG states:

**FIELD SYNC** — ( $\overline{FS}$ ) — The high to low transition of the FS output coincides with the end of active display area. During this time interval an MPU may have total access to the display RAM without causing undesired flicker on the screen. The Low to High transition of  $\overline{FS}$  coincides with the trailing edge of the vertical synchronization pulse.

**HORIZONTAL SYNC** — ( $\overline{HS}$ ) — The  $\overline{HS}$  pulse is in coincidence with the horizontal synchronization pulse furnished to the television receiver by the VDG. The high to low transition of the HS output coincides with the leading edge of the horizontal synchronization pulse.

**ROW PRESET** — ( $\overline{RP}$ ) — If desired, an external character generator ROM may be used with the VDG. However, an external four bit counter must be added to supply row selection. The counter is clocked by the  $\overline{HS}$  signal and cleared by the  $\overline{RP}$  signal.

**Mode Control Lines (Input) ( $\overline{A/G}$ ,  $\overline{A/S}$ ,  $\overline{INT/EXT}$ ,  $\overline{GM0}$ ,  $\overline{GM1}$ ,  $\overline{GM2}$ ,  $\overline{CSS}$ ,  $\overline{INV}$ )** — Eight TTL compatible inputs are used to control the operating mode of the VDG.  $\overline{A/S}$ ,  $\overline{INT/EXT}$ ,  $\overline{CSS}$  and  $\overline{INV}$  may be changed on a character by character basis. The  $\overline{CSS}$  pin is used to select between two possible alphanumeric colors; when the VDG is in the alphanumeric mode and between two color sets when the VDG is in the semigraphic 6 and full Graphic mode. Table 1 illustrates the various modes that can be obtained using the mode control lines.

**DISPLAY MODES**

The VDG is capable of generating 12 distinct display modes (refer to Table 1). The color set selection and invert pins will allow variations on certain modes. The VDG will display two alphanumeric modes with two compatible semigraphic modes or display one of eight full graphic modes. A detailed description of the various modes of operation follows. A summary of major modes can be found in Table 2.

**ALPHANUMERIC DISPLAY MODES** — All alphanumeric modes occupy an 8 x 12 dot character matrix box and there are 32 x 16 character boxes per TV frame. Each horizontal dot (dot-clock) corresponds to one-half the period duration of the 3.58 MHz clock and each vertical dot is one scan line. One of two colors for the lighted dots may be selected by the color set select pin. An internal ROM will generate 64 ASCII display characters in a standard 5 x 7 box. Six bits of the eight-bit data word are used for the ASCII character generator and the two bits not used can be used to implement inverse video or color switching on a character by character basis. A 512 word display memory is required for this class of display.

The ALPHA SEMIgraphics-4 mode translates bits zero through three into a 4 x 6 dot element in the standard 8 x 12 dot box. Three data bits may be used to select one of eight colors for the entire character box. The extra bit is available to implement mode switching on the fly. A 512 word display memory is required. A density of 64 x 32 elements is available in the display area. The element area is four dot-clocks wide by six lines high.

The ALPHA SEMIgraphics-6 mode maps six 4 x 4 dot elements into the standard 8 x 12 dot alphanumeric box, a screen density of 64 x 48 elements is available. Six bits are used to generate this map and two data bits may be used to select one of four colors in the display box. The element area is four dot-clocks wide by four lines high.

**FULL GRAPHIC MODE** — There are eight full graphic modes available from the VDG. These modes require 1K to 6K bytes of memory. The eight full-graphic modes include an outside color border in one of two colors depending upon the color set select pin ( $\overline{CSS}$ ). The  $\overline{CSS}$  pin selects one of two sets of four colors in the four color graphic modes.

**The 64 x 64 Color Graphics Mode** — The 64 x 64 color graphics mode generates a display matrix of 64 elements wide by 64 elements high. Each element may be one of four colors. A 1K x 8 display memory is required. Each pictel equals four dot-clocks by three scan lines.

**The 128 x 64 Graphics Mode** — The 128 x 64 graphics mode generates a matrix 128 elements wide by 64 elements high. Each element may be either ON or OFF. However, the entire display may be one of two colors, selected by using the color set select pin. A 1K x 8 display memory is required. Each pictel equals two dot-clocks by three scan lines.

**The 128 x 64 Color Graphics Mode** — The 128 x 64 color graphics mode generates a display matrix 128 elements wide by 64 elements high. Each element may be one of four colors. A 2K x 8 display memory is required. Each pictel equals two dot-clocks by three scan lines.

**The 128 x 96 Graphics Mode** — The 128 x 96 graphics mode generates a display matrix 128 elements wide by 96 elements high. Each element may be either ON or OFF. However, the entire display may be one of two colors selected by using the color set select pin. A 2K x 8 display memory is required. Each pictel equals two dot-clocks by two scan lines.

**The 128 x 96 Color Graphics Mode** — The 128 x 96 color graphics mode generates a display 128 elements wide by 96 elements high. Each element may be one of four colors. A 3K x 8 display memory is required. Each pictel equals two dot-clocks by two scan lines.

**The 128 x 192 Graphics Mode** — The 128 x 192 graphics mode generates a display matrix 128 elements wide by 192 elements high. Each element may be either ON or OFF, but the ON elements may be one of two colors selected with color set select pin. A 3K x 8 display memory is required. Each pictel equals two dot-clocks by one scan line.

**The 128 x 192 Color Graphics Mode** — The 128 x 192 color graphics mode generates a display 128 elements wide by 192 elements high. Each element may be one of four colors. A 6K x 8 display memory is required. A detailed description of the VDG modes is given in Table 3. Each pictel equals two dot-clocks by one scan line.

**The 256 x 192 Graphics Mode** — The 256 x 192 graphics mode generates a display 256 elements wide by 192 elements high. Each element may be either ON or OFF, but the ON element may be one of two colors selected with the color set select pin. A 6K x 8 display memory is required. Each pictel equals one dot-clock by one scan line.

TABLE 1 - TABLE OF MODE CONTROL LINES (INPUTS)

A/c	A/s	INT/EXT	INV	GM2	GM1	GM0	ALPHA/GRAPHIC MODE SELECT
0	0	0	0	X	X	X	Internal Alphanumerics
0	0	0	1	X	X	X	Internal Alphanumerics Inverted
0	0	1	0	X	X	X	External Alphanumerics
0	0	1	1	X	X	X	External Alphanumerics Inverted
0	1	0	X	X	X	X	Semigraphics - 4
0	1	1	X	X	X	X	Semigraphics - 6
1	X	X	X	0	0	0	64 x 64 Color Graphics
1	X	X	X	0	1	0	128 x 64 Graphics
1	X	X	X	0	1	1	128 x 96 Color Graphics
1	X	X	X	1	0	0	128 x 96 Graphics
1	X	X	X	1	0	1	128 x 192 Graphics
1	X	X	X	1	1	0	128 x 192 Color Graphics
1	X	X	X	1	1	1	256 x 192 Graphics

TABLE 2 - SUMMARY OF MAJOR MODES

MAJOR MODE ONE  
TABLE OF ALPHA MINOR MODES

Title	Memory	Colors	Display Elements
Alphanumeric (Internal)	512 x 8	2	Display Elements
Alphanumeric (External)	512 x 8	2	Display Elements
Alpha Semig-4	512 x 8	4	Box Element
Alpha Semig-6	512 x 8	4	Box Element

MAJOR MODE TWO  
TABLE OF MINOR GRAPHICS MODES

Title	Memory	Colors	Comments
64 x 64 Color Graphic	1K x 8	4	Matrix 64 x 64 Elements
128 x 64 Graphics*	1K x 8	2	Matrix 128 elements wide by 64 elements high
128 x 64 Color Graphic	2K x 8	4	Matrix 128 elements wide by 64 elements high
128 x 96 Graphics*	1.5K x 8	2	Matrix 128 elements wide by 96 elements high
128 x 96 Color Graphic	3K x 8	4	Matrix 128 elements wide by 96 elements high
128 x 192 Graphics*	3K x 8	2	Matrix 128 elements wide by 192 elements high
128 x 192 Color Graphic	6K x 8	4	Matrix 128 elements wide by 192 elements high
256 x 192 Graphics*	6K x 8	2	Matrix 256 elements wide by 192 elements high

\*Graphics mode turns on or off each element. The color may be one of two.

TABLE 3 - DETAILED DESCRIPTION OF VDG MODES

MODE	VDP PINS		COLOR		TV RETURN		VIDEO DATA BUS	COMMENTS
	INT	EXT	Mode	Color	Mode	Color		
1	0	0	Black	Black	32 Characters	Black	8-bit parallel bus	The ALPHANUMERIC INTERNAL mode uses internal character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory.
2	0	1	Black	Black	16 Characters	Black	8-bit parallel bus	The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory.
3	1	0	Black	Black	32 Characters	Black	8-bit parallel bus	The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory.
4	1	1	Black	Black	16 Characters	Black	8-bit parallel bus	The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory. The ALPHANUMERIC EXTERNAL mode uses external character memory.
5	0	0	Black	Black	64 Display Elements	Black	8-bit parallel bus	The SEMI-GRAPHIC 4 mode uses an internal character memory. The SEMI-GRAPHIC 6 mode uses an internal character memory. The SEMI-GRAPHIC 4 mode uses an internal character memory.
6	0	1	Black	Black	32 Display Elements	Black	8-bit parallel bus	The SEMI-GRAPHIC 4 mode uses an internal character memory. The SEMI-GRAPHIC 6 mode uses an internal character memory. The SEMI-GRAPHIC 4 mode uses an internal character memory.
7	1	0	Black	Black	64 Display Elements	Black	8-bit parallel bus	The SEMI-GRAPHIC 4 mode uses an internal character memory. The SEMI-GRAPHIC 6 mode uses an internal character memory. The SEMI-GRAPHIC 4 mode uses an internal character memory.
8	1	1	Black	Black	32 Display Elements	Black	8-bit parallel bus	The SEMI-GRAPHIC 4 mode uses an internal character memory. The SEMI-GRAPHIC 6 mode uses an internal character memory. The SEMI-GRAPHIC 4 mode uses an internal character memory.
9	0	0	Green	Green	64 Display Elements	Green	8-bit parallel bus	The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM. The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM.
10	0	1	Green	Green	32 Display Elements	Green	8-bit parallel bus	The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM. The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM.
11	1	0	Green	Green	64 Display Elements	Green	8-bit parallel bus	The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM. The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM.
12	1	1	Green	Green	32 Display Elements	Green	8-bit parallel bus	The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM. The GRAPHIC 64 mode uses a maximum of 192K bytes of display RAM.
13	0	0	Green	Green	128 Display Elements	Green	8-bit parallel bus	The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM. The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM.
14	0	1	Green	Green	64 Display Elements	Green	8-bit parallel bus	The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM. The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM.
15	1	0	Green	Green	128 Display Elements	Green	8-bit parallel bus	The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM. The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM.
16	1	1	Green	Green	64 Display Elements	Green	8-bit parallel bus	The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM. The GRAPHIC 128 mode uses a maximum of 384K bytes of display RAM.
17	0	0	Green	Green	192 Display Elements	Green	8-bit parallel bus	The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM. The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM.
18	0	1	Green	Green	96 Display Elements	Green	8-bit parallel bus	The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM. The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM.
19	1	0	Green	Green	192 Display Elements	Green	8-bit parallel bus	The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM. The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM.
20	1	1	Green	Green	96 Display Elements	Green	8-bit parallel bus	The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM. The GRAPHIC 192 mode uses a maximum of 576K bytes of display RAM.
21	0	0	Green	Green	256 Display Elements	Green	8-bit parallel bus	The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM. The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM.
22	0	1	Green	Green	128 Display Elements	Green	8-bit parallel bus	The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM. The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM.
23	1	0	Green	Green	256 Display Elements	Green	8-bit parallel bus	The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM. The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM.
24	1	1	Green	Green	128 Display Elements	Green	8-bit parallel bus	The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM. The GRAPHIC 256 mode uses a maximum of 1024K bytes of display RAM.

TABLE 3 – DETAILED DESCRIPTION OF VDG MODES

VDG PINS										COLOR			TV SCREEN		VDG DATA BUS		COMMENTS
INT	EXT	GM2	GM1	GMD	CSS	INV	Character Color	Background	Border	Display Mode	Detail	VDG DATA BUS	COMMENTS				
0	0	0	X	X	X	0	Green Black Orange Black	Black Green Black Orange	Black Black	32 Characters across 16 Characters down			The ALPHANUMERIC INTERNAL mode uses an internal character generator which contains the following five dot by seven dot characters @ABCDEFGHIJKLIMNOPQRSTUWXYZ[ ] _ - SP ' " \$ % & ' ( ) * + , - / 0 1 2 3 4 5 6 7 8 9 < > ? The six bit ASCII code leaves two bits free and these may be externally connected to the mode pins (A/G, A/S, INT/EXT, GM2, GM1, GMD, CSS or INV).				
0	0	1	X	X	X	0	Green Black Orange Black	Black Green Black Orange	Black Black	32 Characters across 16 Characters down			The ALPHANUMERIC EXTERNAL mode uses an external character generator as well as a row counter. Thus, custom character fonts are graphic symbol sets with up to 256 different eight dot x 12 dot "characters" may be displayed.				
0	1	0	X	X	X	X	Lx C2 C1 C0 0 X X X 1 0 0 0 1 0 0 1 1 0 1 0 1 0 1 1 1 1 0 0 1 1 0 1 1 1 1 0 1 1 1 1	Color Black Green Yellow Blue Red Buff Cyan Magenta Orange	Black	64 Display elements across 32 Display elements down			The SEMIGRAPHICS FOUR mode uses an internal "course graphics" generator in which a rectangle (eight dots by twelve dots) is divided into four equal parts. The luminance of each part is determined by a corresponding bit on the VDG data bus. The color of illuminated parts is determined by three bits.				
0	1	1	X	X	X	0	Lx C1 C0 0 X X 1 0 0 1 0 1 1 1 0 1 1 1 1 0 X 1 0 X 1 0 X 1 1 0 1 1 0 1 1 1	Color Black Green Yellow Blue Red Buff Cyan Magenta Orange	Black	64 Display elements across 48 Display elements down			The SEMIGRAPHICS SIX mode is similar to the SEMIGRAPHICS FOUR mode with the following differences. The eight dot by twelve dot rectangle is divided into six equal parts. Color is determined by the two remaining bits.				
1	1	X	X	0	0	0	C1 C0 0 0 0 1 1 0 1 1 0 1 0 0 1 0 1 1 1 0 1 1	Color Black Green Yellow Blue Red Buff Cyan Magenta Orange	Green Buff	64 Display elements across 64 Display elements down			The GRAPHICS ONE C mode uses a maximum of 1024 bytes of display RAM in which one pair of bits specifies one picture element.				
1	1	X	X	0	0	1	Lx 0 1	Color Black Green Buff	Green Buff	128 Display elements across 64 Display elements down			The GRAPHICS ONE R mode uses a maximum of 1024 bytes of display RAM in which one bit specifies one picture element.				
1	1	X	X	0	0	1	Same color as Graphics one C		Green Buff	128 Display elements across 64 Display elements down			The GRAPHICS TWO C mode uses a maximum of 2048 bytes of display RAM in which one pair of bits specifies one picture element.				
1	1	X	X	0	1	0	Same color as Graphics one R		Green Buff	128 Display elements across 96 Display elements down			The GRAPHICS TWO R mode uses a maximum of 1536 bytes of display RAM in which one bit specifies one picture element.				
1	1	X	X	1	0	0	Same color as Graphics one C		Green Buff	128 Display elements across 96 Display elements down			The GRAPHICS THREE C mode uses a maximum of 3072 bytes of display RAM in which one pair of bits specifies one picture element.				
1	1	X	X	1	0	1	Same color as Graphics one R		Green Buff	128 Display elements across 192 Display elements down			The GRAPHICS THREE R mode uses a maximum of 3072 bytes of display RAM in which one bit specifies one picture element.				
1	1	X	X	1	1	0	Same color as Graphics one C		Green Buff	128 Display elements across 192 Display elements down			The GRAPHICS SIX C mode uses a maximum of 6144 bytes of display RAM in which one pair of bits specifies one picture element.				
1	1	X	X	1	1	1	Same color as Graphics one R		Green Buff	256 Display elements across 192 Display elements down			The GRAPHICS SIX R mode uses a maximum of 6144 bytes of display RAM in which one bit specifies one picture element.				