Note. SK1115 kit includes: MM57100N, MM53104N and LM1889N

MM57100 TV game circuit

general description

The MM57100 TV Game Chip provides all of the logic necessary to generate backgrounds, paddles, ball and digital scoring for three games: Hockey, Tennis and Handball. All games are in color and have sound. The MM57100 was designed for low system cost and is aimed at the high volume consumer marketplace. It generates all the necessary timing (sync, blanking and burst) to interface to a standard TV receiver, and interfaces directly to the antenna terminals of a TV with the addition of a chroma, audio and RF modulator. If mounted directly into a receiver, much of this circuitry can be eliminated. The chip requires the true and complement clocks of 1.0227 MHz (3.579545 MHz ÷ 3.5). *Figure 1* shows a block diagram of a complete TV Game System.

The paddles for the games are controlled by two external RC networks. R and C provides for full screen movement by developing a time delay of about 16.5 ms. For Hockey and Tennis, each of the player paddles can be made to be either large, medium or small in size, thus allowing for handicapping. The size of a player paddle is modified by moving the paddle to either the top or bottom boundary and depressing the game reset button. In Handball, the players can modify the paddles as described above, but both players must use the same size paddle.

Single player "practice," can be created by connecting the two player paddle input lines on the MM57100 to a single external RC network. Single player operation can be achieved for all three games. Thus the MM57100 can actually play six games—three single player games and three dual player games.

The player paddles are divided into nine different areas that define eight angles at which the ball will reflect upon incidence. The top-most area of the player paddle will reflect the ball with the most upward direction, the areas towards the bottom will reflect the ball with the most downward direction. And the very bottom of the paddle will cause the ball to go up at a sharp angle, simulating a "wood" or handle shot. The areas in between will give reflections with less of an angle. There are two areas in the center of the player paddle which will make the ball have zero vertical velocity. The player paddles are transparent in one direction so that in Hockey the ball can rebound off the back wall and pass through the defensive player paddle. The machine paddles in Hockey are also transparent in one direction.

The ball is always served by the player who won the last point. The serve comes about 1.6 seconds from the time of the score and it is served from the paddle. This allows for a more realistic situation: the server can "place" his shot. After four player paddle hits, the ball speeds up to twice the initial velocity. Each time the ball strikes an object, a signal is generated at the audio output for the duration of the frame and one more full frame. When the ball strikes the boundaries or a machine paddle, it bounces off the object under the rule that the angle of incidence is equal to the angle of reflection. Regardless of the angle that the ball is traveling as it hits the front of the player paddles, it will reflect as a function of which segment it hits.

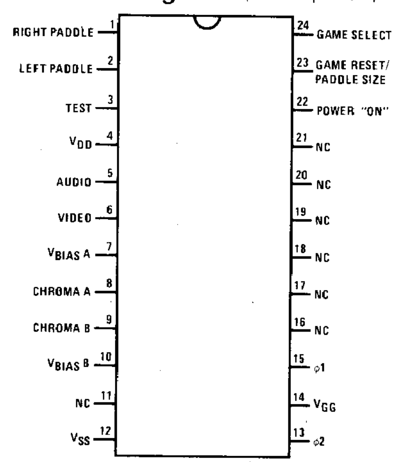
The score is automatically blanked when the ball is put into play. It remains blanked until a miss is recorded and it is then properly incremented and displayed. The game is completed when one of the players reaches 15 points. At this time, the score remains on and the serve is inhibited until the Game Reset is depressed. Both the Game Reset and Game Select inputs are debounced for 16.5 ms.

The video output signal contains horizontal and vertical blanking, horizontal and vertical sync and the black and white information necessary to generate the picture on a TV receiver through the antenna input. The picture is not interlaced. Chroma outputs provide the color and burst information and are properly timed with the video.

features

- Three games: Hockey, Tennis and Handball
- All games in full color
- Ball speed doubles after fourth hit
- Segmented paddles for automatic ball spin
- Adjustable paddle size/handicapped play
- Automatic digital scoring
- Sound
- Serve from paddles
- Designed to interface with a minimum effort to a standard television receiver

connection diagram (DIP Top View)



Order Number MM57100N
See Package 22

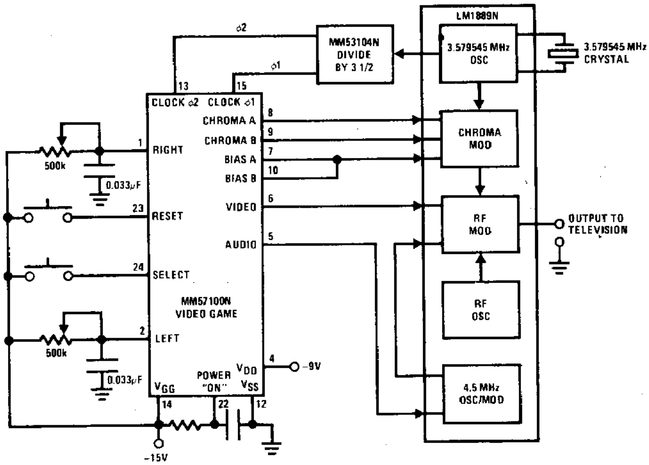


FIGURE 1. Video Game System Diagram

GAME DESCRIPTION

Tennis

Tennis consists of a green court with a blue border, a yellow net, orange paddles and a light green ball. It is played by two players who, through the use of their individual controllers, can vertically raise or lower their paddles. Play starts when the machine automatically serves the ball cross court. This can be from either the left or the right. The player who is served must hit the ball back to his opponent, who must then return it.

As the volley begins, the speed of the ball increases once, making it more difficult to return. The speed change occurs on the fourth hit. When either player misses the ball, a point is scored for his opponent and the next serve comes to him after a wait of 1.6 seconds. To increase the play value, the ball can bounce off both the top and bottom walls. In addition, before the play begins, each player can choose a large, medium or small paddle, depending on his playing skill. The paddles are sectioned, giving a "spin" effect to the ball.

The score, which is yellow, is automatically displayed in large, easy-to-read numerals. The score appears when the ball is missed and remains on until the ball is served. Play ends when the first player reaches 15 points. At the end of the game, the score remains on until the game is reset.

Hockey

Hockey consists of a blue playing field which is surrounded by yellow walls, two yellow player-controlled goalies, six light yellow machine-controlled forwards and a light blue hockey puck.

Hockey, while similar to tennis, is a much faster and more exciting game. Each player controls only his goalie, who moves in a vertical motion. In addition, each player has three forward men who also move vertically. These men are not under player control but move up and down, as a group, automatically. As in tennis, the opening serve comes cross court and can come to either player. Further serves are to the player who has just lost a point.

Since each player has four men who can return the puck, the play is very fast. To make it even more difficult, a point can only be made when the puck slips through either player's goal – a small opening located directly in the middle of the side walls. Since only a small portion of the left and right walls is used for scoring, the puck can essentially rebound off all four walls. Scoring is the same as in tennis – first player to reach 15 is the winner. The score is yellow.

Handball

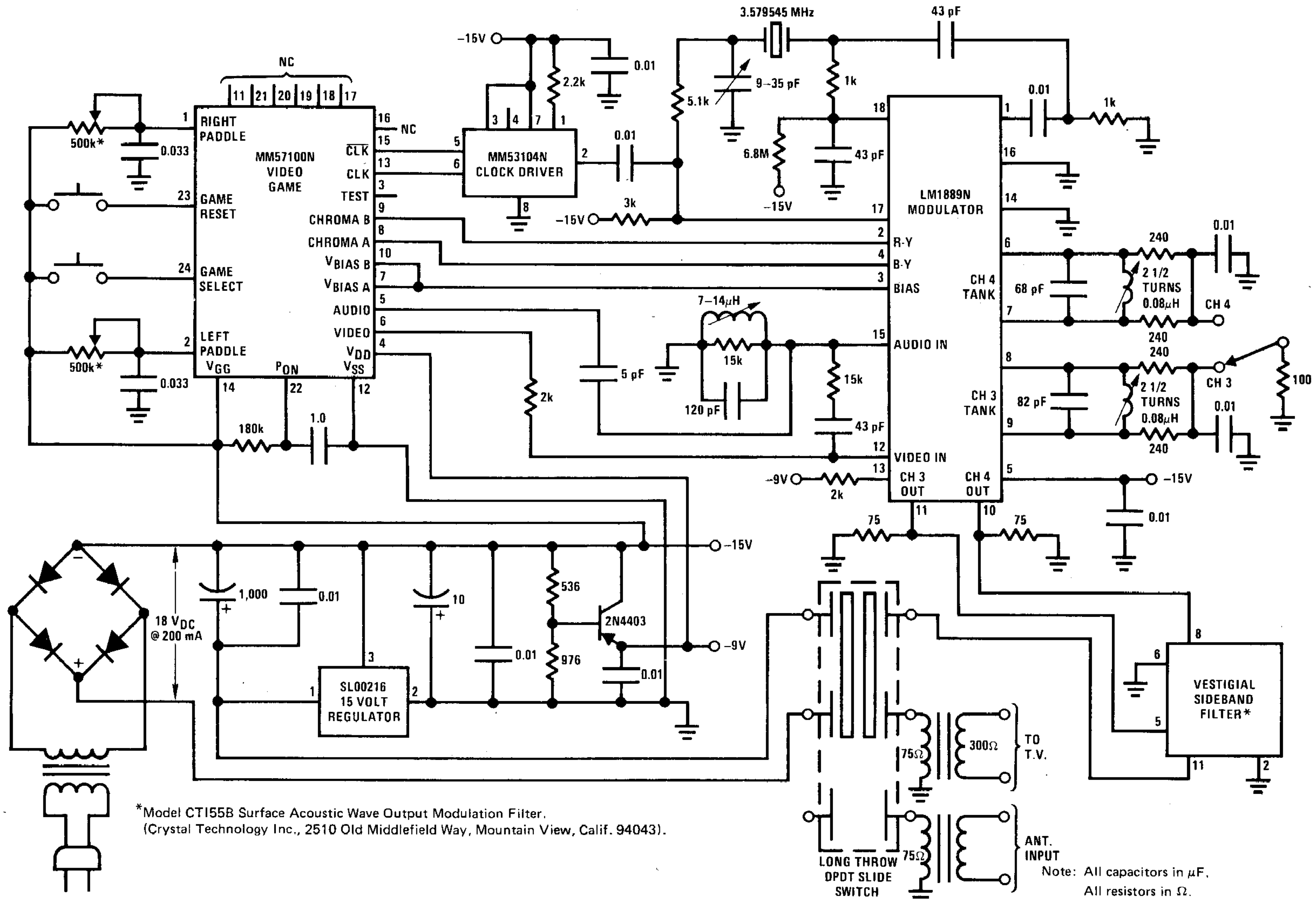
Handball consists of a brown court, two paddles – one blue and one orange, and a yellow ball. It plays identical to tennis except only one player plays at a time and both are on the same side of the court, playing against the opposite wall. After the ball is served, the serving player disappears from the screen and the other player's paddle appears. He must hit it, or he loses the point and the other player serves again. If he hits it, his paddle disappears and the other paddle comes on the screen. The other player must return it to the wall. The object of the game is to keep the ball in play by continuously hitting it to the back court wall. The ball can be reflected off three sides – the top, bottom and right wall. The first player to score 15 is the winner. The score colors match the paddle colors – one blue and one orange.

SUMMARY

Table 1 describes how the game will appear on a standard 25" TV. The actual appearance will vary somewhat from set to set as a function of color control settings, fine tuning, overscan, etc. Table 2 and *Figure 10* define the Chroma Outputs and the approximate color they generate.

SYSTEM CONFIGURATION

Figure 2 is a detailed schematic of how the MM57100 TV Game Chip would appear in a completed system, including the MM53104 clock generator and the LM1889 channel modulator.



*Model CTI55B Surface Acoustic Wave Output Modulation Filter. (Crystal Technology Inc., 2510 Old Middlefield Way, Mountain View, Calif. 94043).

Note: All capacitors in μF.
All resistors in Ω.

*CENTRALAB Model 2 ULTRALIFE potentiometer or equivalent.

FIGURE 2. Schematic Diagram

4

dc electrical characteristics $0°C \leq T_A \leq 75°C$

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Operating Supply Voltages					
	$V_{SS} - V_{DD}$	$14.25 \leq V_{SS} - V_{GG} \leq 15.75$	8.5	9	9.5	V
	$V_{SS} - V_{GG}$	$8.5 \leq V_{SS} - V_{DD} \leq 9.5$	14.25	15	15.75	V
	Operating Supply Current					
I_{DD}		$V_{DD} = V_{SS} - 9.5V$		35		mA
I_{GG}		$V_{GG} = V_{SS} - 15.75V$		15		mA
	Osc. Input Levels, $\phi1$, $\phi2$ *(Figure 3)*					
V_{IH}	Logical High Level		$V_{SS}-0.5$		V_{SS}	V
V_{IL}	Logical Low Level		V_{GG}		$V_{GG}+0.5$	V
	Chroma A Output Levels *(Figure 4)*	$C_L = 50$ pF, $I_{DC} = 0$, $8.5 \leq V_{SS} - V_{DD} \leq 9.5$, (Typical values are for $V_{SS} - V_{DD} = 9V$). All voltages specified with respect to V_{DD}				
V_{A1}	$A1 = 0.465 \times (V_{SS} - V_{DD})$		3.95	4.18	4.42	V
Ro_{A1}	Output Impedance		900		2060	Ω
V_{A0}	$A0 = 0.298 \times (V_{SS} - V_{DD})$		2.53	2.68	2.83	V
Ro_{A0}	Output Impedance		790		2060	Ω
V_{ABURST}	$A_{BURST} = 0.238 \times (V_{SS} - V_{DD})$		1.82	1.93	2.04	V
Ro_{ABURST}	Output Impedance		710.0		2030	Ω
V_{A3}	$A3 = 0.134 \times (V_{SS} - V_{DD})$		1.13	1.2	1.27	V
Ro_{A3}	Output Impedance		520.0		2100	Ω
	Chroma B Output Levels *(Figure 4)*	$C_L = 50$ pF, $I_{DC} = 0$, $8.5 \leq V_{SS} - V_{DD} \leq 9.5$. (Typical values are for $V_{SS} - V_{DD} = 9V$). All voltages specified with respect to V_{DD}				
V_{B1}	$B1 = 0.465 \times (V_{SS} - V_{DD})$		3.95	4.18	4.42	V
Ro_{B1}	Output Impedance		900		2060	Ω
V_{B0}	$B0 = 0.298 \times (V_{SS} - V_{DD})$		2.53	2.68	2.83	V
Ro_{B0}	Output Impedance		790		2060	Ω
V_{B3}	$B3 = 0.134 \times (V_{SS} - V_{DD})$		1.13	1.2	1.27	V
Ro_{B3}	Output Impedance		520		2100	Ω
	Chroma A Bias and Chroma B Bias Output Levels	$C_L = 50$ pF, $I_{DC} = 0$, $8.5 \leq V_{SS} - V_{DD} \leq 9.5$. (Typical values are for $V_{SS} - V_{DD} = 9V$). All voltages specified with respect to V_{DD}				
$V_{BIASA}, V_{BIASB} = 0.298\ (V_{SS} - V_{DD})$			2.53	2.68	2.83	V
Ro_{BIASA}, Ro_{BIASB}			790		2060	Ω
	Chroma and Chroma Bias Output Offset Voltages	$C_L = 50$ pF, $\lvert I_{DC}\rvert \leq 50\mu A$, $\lvert I_{CHROMA} - I_{BIAS}\rvert \leq 5\mu A$, $\lvert I_{CHROMAA} - I_{CHROMAB}\rvert \leq 5\mu A$				
V_{OS}				10	50	mV

dc electrical characteristics (con't) $0°C \leq T_A \leq 75°C$

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Video Output Levels *(Figure 5)*	C_L = 50 pF, I_{DC} = 0, 8.5 = $V_{SS} - V_{DD} \leq$ 9.5. All voltages specified with respect to V_{DD}.(Typical values are for $V_{SS} - V_{DD}$ = 9V)				
V_{SYNC}	V_{SYNC} = 0.444 x ($V_{SS} - V_{DD}$)		3.77	4	4.22	V
Ro_{SYNC}	Output Resistance		906		2080	Ω
V_{BLANK}	V_{BLANK} = 0.333 x ($V_{SS} - V_{DD}$) = 0.75 x V_{SYNC}		2.83	3	3.18	V
Ro_{BLANK}	Output Resistance		835		2080	Ω
V_{DARK}	V_{DARK} = 0.242 x ($V_{SS} - V_{DD}$) = 0.545 x V_{SYNC}		2.06	2.18	2.30	V
Ro_{DARK}	Output Resistance		726		2030	Ω
V_{LIGHT}	V_{LIGHT} = 0.148 x ($V_{SS} - V_{DD}$) = 0.383 x V_{SYNC}		1.26	1.33	1.41	V
Ro_{LIGHT}	Output Resistance		556		2040	Ω
	Audio Output Level *(Figure 6)*	R_{LOAD} = 100k, C_{LOAD} = 20 pF				
V_{OUT}				V_{DD}		V
	Output Resistance to V_{DD}					
$Ro_{"ON"}$	"ON" Resistance	$V_{OL} \leq V_{DD}$ +0.5		1.0	5	kΩ
$Ro_{"OFF"}$	"OFF" Resistance	$V_{OH} \geq V_{DD}$ + 3.0	50	500		kΩ
C_{OUT}				5		pF
	Reset, Test and Game Select Input Levels					
V_{IH}	Logical High Level		V_{SS}−1.5		V_{SS}	V
V_{IL}	Logical Low Level		V_{DD}		V_{DD}+2.5	V
	Paddle 1 and Paddle 2 Input Levels *(Figure 7)*	8.5 $\leq V_{SS} - V_{DD} \leq$ 9.5				
V_{PI}	Input Trip Level		V_{DD}−0.4	V_{DD}	V_{DD}+0.4	V
V_{OH}	Logical High Output Reset Level	R_{LOAD} = 15 kΩ to V_{GG}, C_{LOAD} = 0.1μF, 10%	V_{SS}−2.5		V_{SS}	V
	Power "ON" Clear Input Levels *(Figure 8)* See Note 6					
V_{CLR}	Input Trip Level	R_{LOAD} = 180k, 10%, C_{LOAD} = 1μF, 10%	V_{DD} −0.5	V_{DD}	V_{DD}+0.5	V
V_{OH}	Logical High Output Reset Level		V_{SS}−2.5		V_{SS}	V
e_n	**Noise Levels on Chroma A, Chroma B, and Video Outputs**	8.5 $\leq V_{SS} - V_{DD} \leq$ 9.5, 14.25 $\leq V_{SS} - V_{GG} \leq$ 15.75, C_{LOAD} = 50 pF, $\|I\| \leq$ 50μA	−200		200	mV

Note 1: Chroma A, Chroma B and the Chroma bias output levels are specified for dc current = 0. Typical dc loading conditions are 30μA or less. The resistor network in *Figure 9(a)* can be used to determine the shift and interaction in outputs for dc load conditions.

Note 2: Video output levels are specified for dc current = 0. Any other loading conditions will influence the output levels and the resistor network in *Figure 9(b)* can be used to calculate output levels. Typical dc currents are 30μA or less.

Note 3: All diffused resistors have a ±30% tolerance, and tracking of tolerance can be assumed.

Note 4: All MOS switch impedances include all variations, i.e., due to process, and supply variations, tracking of MOS switch impedances can be assumed.

Note 5: Tracking of diffused resistor tolerances and MOS device tolerances *cannot* be assumed.

Note 6: Power On Clear input pin is reset by the MM57100 to the V_{OH} level near the end of the internal Power On Clear cycle, as shown in *Figure 8.*

ac electrical characteristics (0°C to +70°C, except where otherwise noted)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Osc Inputs, $\phi 1$ and $\phi 2$ Input Frequency *(Figure 3)*			1.0227		MHz
	Rise and Fall Times					
t_r, t_f					40	ns
t_{dL1}					10	ns
t_ϕ				0.9778		μs
t_{pw1}			0.405			μs
t_{pw2}			0.380			μs
V_{OL1}			$V_{SS}-1.0$	$V_{SS}-0.5$	V_{SS}	V
V_{OL2}			$V_{SS}-2.0$	$V_{SS}-1.0$	V_{SS}	V
	Chroma A and Chroma B Output Timing *(Figure 4)*	C_L = 50 pF, $I_{DC} \leq 50\mu A$				
t_{rA}				175	225	ns
t_{fA}				175	225	ns
t_{rB}				175	225	ns
t_{fB}				175	225	ns
t_{SCB}				450		ns
t_{rCB}				175		ns
t_{fCB}				175		ns
t_{CL1}				0		ns
t_{CL2}				0		ns
t_{BURST}				2900		ns
	Video Output Timing *(Figure 5)*	C_{LOAD} = 50 pF, $\|I_{DC}\| \leq 50\mu A$				
t_{rv}				250	500	ns
t_{fv}				250	500	ns
t_{rS}				250	500	ns
t_{fS}				250	500	ns
t_{rL}				150	225	ns
t_{fL}				150	225	ns
t_{bp}				5		μs
t_{SYNC}				4.5	4.9	μs
t_{fp}				1	1.25	μs
t_{VIDEO}				0.97		μs
t_{BLANK}			10.5	11	11.9	μs
	Audio Output Timing *(Figure 6)*	$\phi 1$, $\phi 2$ inputs = 1.0227 MHz, C_{LOAD} = 20 pF				
f_a	Output Frequency	$\|I_{DC}\| \leq 50\mu A$		491		Hz
	Audio Tone Duration					
t_{ON}			18.55		30.25	ms
t_{OFF}				15		μs
t_{ra}, t_{fa}		C_{LOAD} = 20 pF, R_{EXT} = 120k to V_{SS}		10		μs
t_{ha}				1		ms
t_{pwa}				2.037		ms
	Player Paddle Timing *(Figure 7)*	C_{LOAD} = 0.1μF + 10%, $R_{LOAD} \geq 15\ k\Omega$ (to V_{GG})				
t_{PH}	Paddle High (25H)		1.58			ms
t_{PL}	Paddle Low (215H)				13.7	ms
t_{RP}					1.2	ms
	Power "ON" Clear Timing *(Figure 8)*	RC > 138 ms, R = 180k, 10%; C = 1μF, 10%				
t_{dcl}			60			ms
t_{POWER}					30	ms

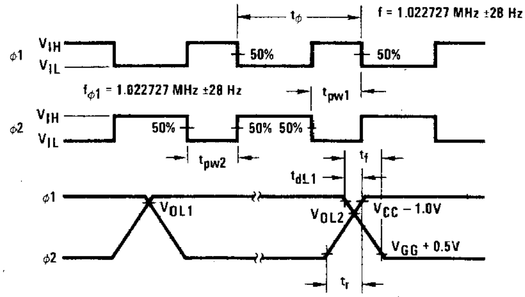


FIGURE 3. Input Clock Waveforms

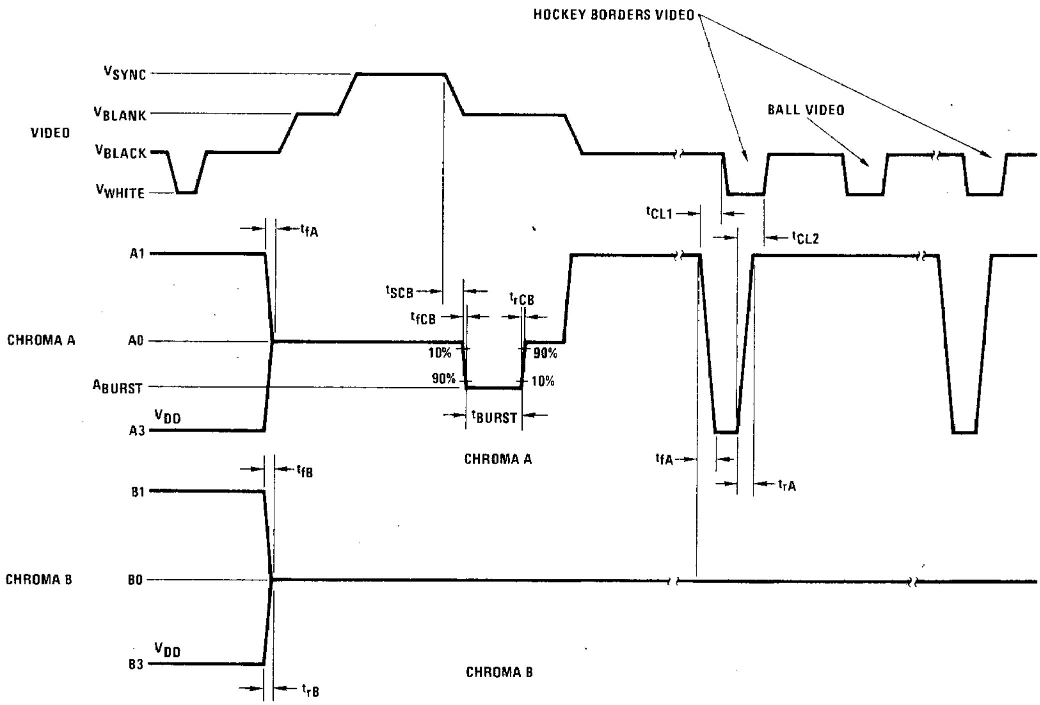
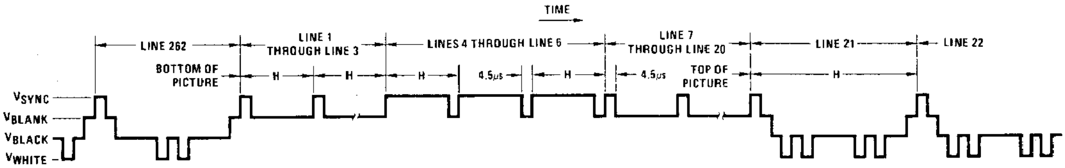


FIGURE 4. Video-Chroma Timing



H ≅ 63.557μs

Note: Interlaced scan and equalization pulses are not used.

FIGURE 5(a). Video Output Waveform

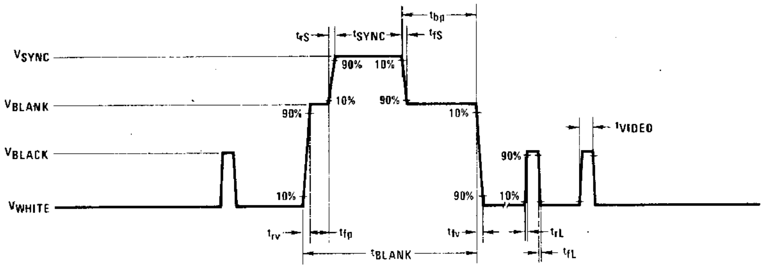


FIGURE 5(b). Composite Video Timing and Levels

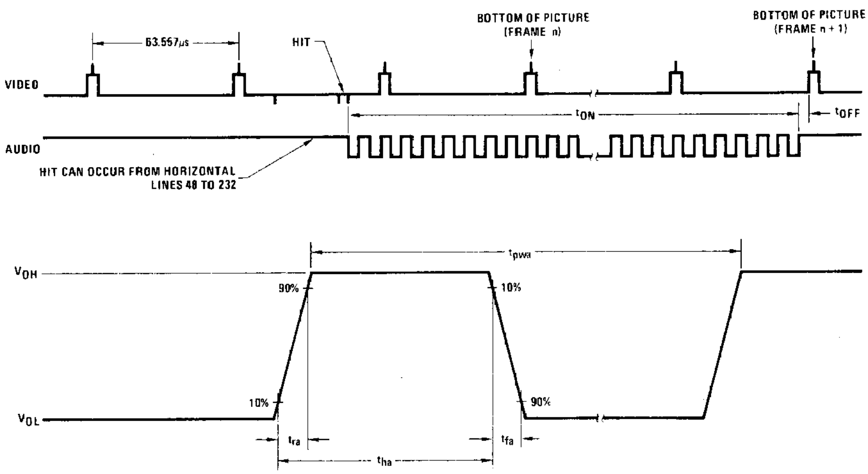


FIGURE 6. Audio Output Timing

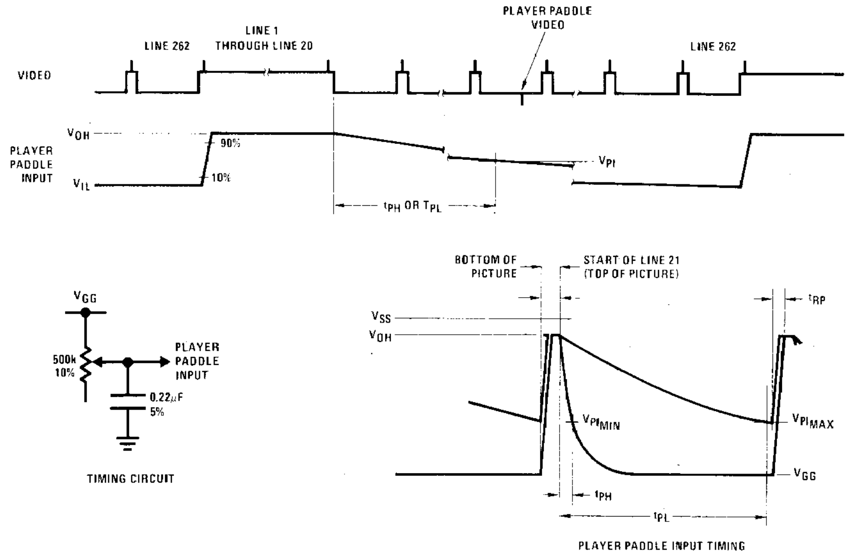
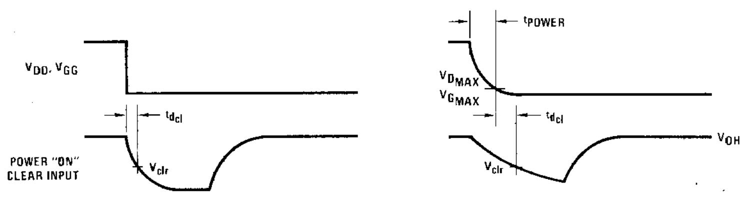


FIGURE 7. Player Paddle Inputs



(a) Fast Power Supply Edges

(b) Slow Power Supply Edges

FIGURE 8. Power "ON" Clear Input Timing

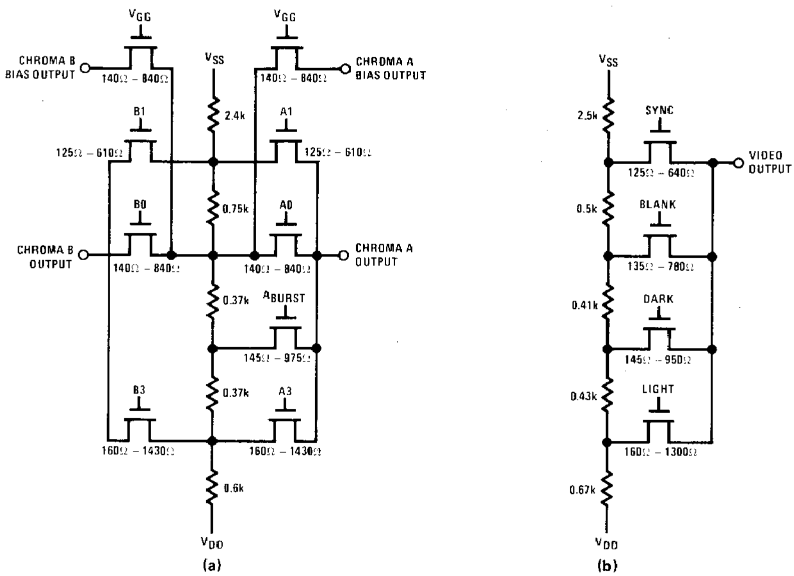


FIGURE 9. Chroma and Video Output Networks (See Notes on Page 4-41)

TABLE I. Game Colors and Size on a 25" TV

ELEMENT	CHROMA OUTPUT	VIDEO OUTPUT	APPR. COLOR	APPR. SIZE	COMMENTS
Tennis Background	A1B0	Light	Blue		
Tennis Field	A0B3	Dark	Cyan	13.2 x 16.8 inches^2	
Tennis Ball	A0B3	Light	Cyan	0.5 x 0.5 inches^2	
Tennis Score	A3B0	Light	Yellow	4 x 5 inches^2	Blanked during play
Tennis Net	A3B0	Light	Yellow	0.5 x 13.2 inches^2	
Tennis Left Player	A3B1	Light	Orange	3 sizes	2.4, 1.2 or 0.6 inches x 0.5 inches independent of other paddle
Tennis Right Player	A3B1	Light	Orange	3 sizes	2.4, 1.2 or 0.6 inches x 0.5 inches independent of other paddle
Handball Background	A3B0	Light	Yellow		
Handball Field	A3B0	Dark	Yellow	13.2 x 16.8 inches^2	
Handball Ball	A3B0	Light	Yellow	0.5 x 0.5 inches^2	
Handball Left Score	A3B1	Light	Orange	4 x 5 inches^2	Blanked during play
Handball Right Score	A1B0	Light	Blue	4 x 5 inches^2	Blanked during play
Handball Left Player	A3B1	Light	Orange	3 sizes	2.4, 1.2 or 0.6 x 0.5 inches, same as other paddle
Handball Right Player	A1B0	Light	Blue	3 sizes	2.4, 1.2 or 0.6 x 0.5 inches, same as other paddle
Hockey Background	A1B0	Dark	Blue		
Hockey Field	A1B0	Dark	Blue	13.2 x 16.8 inches^2	
Hockey Border	A3B0	Light	Yellow		
Hockey Puck	A1B0	Light	Blue	0.5 x 0.5 inches^2	
Hockey Score	A3B0	Light	Yellow	4 x 5 inches^2	Blanked during play
Hockey Left Player	A3B0	Light	Yellow	3 sizes	2.4, 1.2 or 0.6 x 0.5 inches independent of other paddle
Hockey Right Player	A3B0	Light	Yellow	3 sizes	2.4, 1.2 or 0.6 x 0.5 inches independent of other paddle
Hockey Machine Forwards	A3B0	Light	Yellow	0.5 x 0.6 inches^2	
Hockey Goals	A1B0	Light	Blue	4.6 x 0.5 inches^2	Hole in the Border

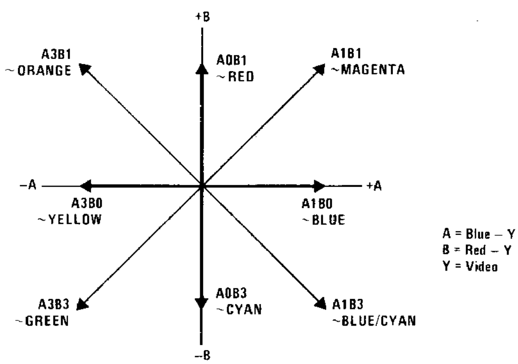


FIGURE 10. Chroma Outputs/Color Phase Diagram

TABLE II. Chroma Outputs vs Approximate Color

CHROMA A AND CHROMA B OUTPUTS	APPROXIMATE COLOR
A0, B0	Light Gray
A0, B1	Red
A0, B3	Cyan
A1, B0	Blue
A1, B1	Magenta
A1, B3	Blue Cyan
A3, B0	Yellow
A3, B1	Orange
A3, B3	Green
A_{BURST}, B0	Color Burst

DESIGN CONSIDERATION FOR THE PLAYER PADDLE INPUTS

Calculations are based on an input waveform at the "PLAYER PADDLE" input:

$$V_{IN} = V_{IH} + (1 - e^{-t/RC})(V_{GG} - V_{IH})$$

A solution for t = RC is done, at the input trip point where $V_{IN} = V_{TRIP} = V_{DD} \pm 0.4V$, and $t = t_d$.

$$RC = \frac{-t_d}{\ln\left[\frac{V_{GG} - V_{DD} \pm 0.4V}{V_{GG} - V_{IH}}\right]}$$

Over the design range of V_{DD}, V_{GG} and V_{IH}, the denominator has a range

$$-1.187 \leq \ln(x) \leq -0.5864 \text{ where } x = \frac{V_{GG} - V_{DD} \pm 0.4V}{V_{GG} - V_{IH}}$$

The time delays required vary from a minimum of t_{dT} = 1.58 ms for the player paddle positioned at the top of the screen, to a delay of t_{dB} = 13.7 ms for the player paddle positioned at the bottom of the screen. For these time delays, the ranges of RC are:

$$(RC)_{TMIN} = 1.33 \text{ ms} \leq \frac{t_{dT}}{\ln\left[\frac{V_{GG} - V_{DD} \pm 0.4V}{V_{GG} - V_{IH}}\right]} \leq (RC)_{TMAX} = 2.69 \text{ ms}$$

for the upper paddle position and

$(RC)_{BMIN}$ = 11.54 ms; $(RC)_{BMAX}$ = 23.36 ms

for the lower paddle position.

Thus, the external RC network must guarantee a minimum RC of 1.33 ms or less and a maximum RC of 23.36 ms or greater.

Calculations of potentiometer resistance based on a linear pot use the formula:

$$R_\theta = \frac{\theta \times R_p}{\theta_{fs}} \pm R_p \cdot L$$

where: R_θ is the potentiometer tap resistance
- θ is the angle of pot rotation beyond 0
- θ_{fs} is the full scale rotation of the pot, ± tolerance
- R_p is the full scale resistance of the pot, ± tolerance
- L is the linearity of the pot

Using RC = t_d, values of θ can be calculated for the required extremes using the expression:

$$\theta = \frac{\left(\frac{t_d}{C} \pm R_p \cdot L\right)\theta_{fs}}{R_p}$$

This expression assumes prior selection of R_p, L, θ_{fs}, and C. This expression can be modified to calculate R_p or C if there is any restriction on the upper limit of θ.

Mechanical variations, either in the potentiometer or the control housing which affect pot rotation should also be considered.

TIMING AND LEVEL DEFINITIONS

t_r, t_f	Rise and fall times of ϕ1 and ϕ2 clock inputs.
t_{dL1}	Delay from the V_{SS} − 1V point of the ϕ2 positive transition to the V_{SS} − 1V point of the ϕ1 negative transition.
t_ϕ	Clock cycle time.
t_{PW1}	Time from 50% point on negative edge of ϕ2 to the 50% point on the negative edge of ϕ1.
t_{PW2}	Pulse width of the ϕ2 input, at the 50% point.
V_{OL1}	Crossover point where ϕ1 = ϕ2 and ϕ1 is on a negative transition.
V_{OL2}	Crossover point where ϕ1 = ϕ2 and ϕ1 is on a positive transition.
t_{rA}, t_{rB}, t_{fA}, t_{fB}	Rise and fall times of the chroma A and chroma B outputs.
t_{SCB}	Delay from start of sync pulse trailing edge to the start of the chroma A output color burst leading edge.
t_{rCB}, t_{fCB}	Rise and fall times of the chroma A output color burst pulse.
t_{BURST}	Chroma A output color burst pulse width.
t_{CL1}	Delay from the start of a chroma output negative transition to the start of the VIDEO output (luminance) transition.
t_{CL2}	Delay from the start of a chroma output positive transition to the start of the VIDEO output (luminance) transition.
t_{rv}, t_{fv}	Rise and fall times of the VIDEO output blanking pulse.
t_{rS}, t_{fS}	Rise and fall times of the VIDEO output SYNC pulse.
t_{rL}, t_{fL}	Rise and fall times of the VIDEO output luminance pulses.
t_{fp}, t_{bp}	Duration of the VIDEO output front porch and back porch.
t_{SYNC}	Duration of the VIDEO output SYNC pulse.
t_{VIDEO}	Duration of the VIDEO output luminance pulses.
t_{BLANK}	Duration of the VIDEO output blanking pulse.
t_{ON}	Duration of the AUDIO output "HIT" tone burst.
t_{OFF}	Delay from the end of the AUDIO output "HIT" tone burst to the start of the VIDEO output blanking pulse.
t_{ra}, t_{fa}	Rise and fall times of the AUDIO output.
t_{ha}	Width of the AUDIO output tone pulse positive level.
t_{pwa}	AUDIO output tone cycle time ($t = 1/f_{AUDIO}$)
t_{RP}	Rise time of the PLAYER PADDLE input.
t_{PH}	Delay time from the top of the picture to the highest player paddle position.
t_{PL}	Delay time from the top of the picture to the lowest player paddle position.
t_{dcl}	Delay from point where the power supplies are within the operating spec to the point where the power-on clear input level is less than V_{CLRI}.
t_{POWER}	Fall time of the power supply at turn-on, to 95% point.
H	One horizontal scan line.