PULNiX

TMC-9700
PROGRESSIVE SCAN CCD
DIGITAL COLOR CAMERA

OPERATIONS
MANUAL

Feb. 1996

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SECTION 1: OPERATION

1.1 OUTLINE

The TMC-9700 is a digital process and output CCD color video camera which uses a 2/3" high resolution progressive scan interline transfer CCD. The CCD camera produces less geometrical distortion and has higher resistance to vibration and shock when compared with a camera using a pickup tube. These features make the camera suitable for both industrial and the most demanding applications. It is especially designed to capture images in progressive scan (non-interlace) format and provides full frame of electronic shutter image as well as normal images and output digital signal for computer interface beside the standard RGB analog output.

The TMC-9700 uses RGB primary color filters to generate excellent color reproduction. The CFA (Color Filter Array) is 3G and R/B staggered structure which is ideal to human color response of resolution. The 3G array can generate the most critical Green pixel signal for the highest resolution horizontally and vertically.

It is essential to use digital processing to utilize such CFA. The TMC-9700 consists the most powerful DSPs which can be externally controlled via RS-232C.

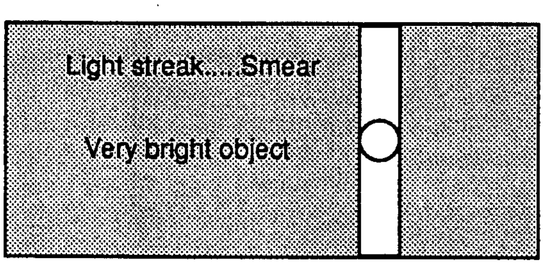
The TMC-9700 features all functions of TM-9700 black and white camera operation which includes asynchronous reset and full frame shutter, frame storage, integration, non-interlace / interlace output, etc..

1.2 SPECIAL CHARACTERISTICS OF A CCD

Smear phenomenon

This phenomenon occurs when shooting a very bright object (such as halogen light, fluorescent lamp, the sun or a strong reflection.) Due to the interline-transfer organization of the CCD image sensors (Refer to the "The Interline-transfer Organization of the CCD Image Sensors", Section 3.3), this phenomenon is caused by electronic charges generated beneath vertical shift registers. It is more visible at high speed shutter application because the short integration signal is similar magnitude as the smear level.

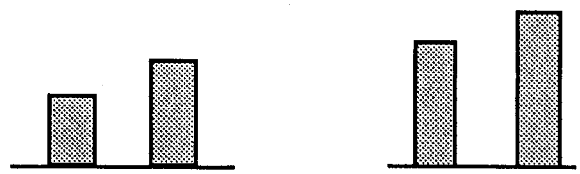
NOTE: PULNiX color cameras contain a filter to minimize smear. Smear should only occur under extremely bright, and point light source conditions.



Patterned noise on the picture at high temperatures

Dark current (thermal noise) is inherent in semiconductors. At room temperature, the amount of dark current in all photosensors is very close. However, as the temperature rises, the amount of dark current increases. As a result, the relative difference between the dark current of each photosensor increases. This difference also causes the patterned noise on the picture.

When CCD is integrated for long period, the dark current is also accumulated to visible level.



False signal

When vertical stripes or straight lines are shot, they may look wavy (Moire effect).

Blemish-free Imagers

CCD photosensor elements generate electronic charges which ultimately produce horizontal and vertical rows in the CCD image sensor. Thus, any malfunctioning photosensor element could eventually cause a blemish on the monitor screen. However, the PULNiX TMC-9700 cameras all have minimum or blemish-free (optional) CCDs to avoid this problem.

Consult the specifications in "Comprehensive Specifications" for details on the blemishes of the TMC-9700.

SECTION 2: COMPREHENSIVE SPECIFICATIONS

Model	TMC-9700
Imager	2/3" Progressive scan interline transfer CCD (8.8 x 6.6 mm)
Pixel	768(H) x 484(V)
Cell size	11.6µm(H) x 13.6µm(V)
Color filter	R, G, B primary color filter (3G, R/B staggered)
Scanning	525 lines 30 Hz progressive scan (asynchronous reset)
	2:1 interlace synchronous output and progressive scan output
Sync	Internal / External fH = 15.734 KHz ± 1% fV = 59.94 Hz
TV resolution	460(H) x 480(V) TV lines
S/N ratio	50 dB (8-bit) (AGC off)
Min. illumination	10 Lux F = 1.4
Video output	RGB and NTSC video = 0.714 Vp-p at 75 Ω (interlace/non-interlace analog video) Digital video = 8 bit x 3 (R,G,B) TTL
Color balance	Auto white balance with teaching trigger External control via RS-232C
AGC	Digital gain control
Gamma	0.45(default) or 1.0 selectable via RS-232C
Lens mount	C-mount
Power req.	12 V DC, 600 mA
Operating temp.	-10°C to +50°C
Vibration & shock	Vibration: 7 G (11Hz to 200Hz), Shock: 70G
Size (W X H X L)	46mm x 51mm x 171.7mm (1.81" x 2.0" x 6.76")
Weight	225 grams (4.3 oz)
Power cable	12P-02
Power supply	PD-12
Auto iris connector	None
Functional options	RS-422 interface, RS-232C interface and software Consult PULNiX for special options
Accessories	30DG-02 digital cable, 50-1050 RGB cable

SECTION 3: THEORY OF OPERATION

3.1 OPERATION PRINCIPLES OF THE CCD

A CCD (Charge Coupled Device) consists of MOS (Metal Oxide-Silicon) capacitors arranged in a regular array. It performs three functions connected with handling electrical charges:

Photoelectric conversion (photo sensor)

Incandescent light generates electrical charges on the MOS capacitors, with the quantity of charge being proportional to the brightness.

Accumulation of electrical charges

When voltage is applied to the electrodes of the CCD, an electrical potential well is formed in the silicon layer. The electrical charge is accumulated in this well.

Transmission of electrical charge

When high voltage is applied to the electrodes, a deeper well is formed. When low voltage is applied, a shallower well is formed. In the CCD, this property is used to transmit electrical charge. When a high volt-age is applied to the electrodes, a deep electric potential well is formed and electrical charge flows in from the neighboring wells. When this is repeated over and over among the regularly arranged electrodes, the electrical charge is transferred from one MOS capacitor to another. This is the principle of CCD electrical charge transmission.

3.2 MECHANISM OF CCD ELECTRICAL CHARGE TRANSMISSION

The TMC-9700 uses a 2-phase drive method CCD. For simplicity, a general 2-phase drive method CCD is explained below.

Figure 1 shows an example of the changes which can occur in potential wells in successive time intervals.

At t1, the electrode voltages are fH1>fH2, so the potential wells are deeper toward the electrode at the higher voltage fH1. Electrical charge accumulates in these deep wells.

At t2, the clock voltages fH1 and fH2 are reversed; now the wells toward the electrode at voltage fH2 become deeper while those toward the electrode at fH1 become shallower. So the wells at fH2 are deeper than those at fH1 and the signal charge flows toward the deeper wells.

At t3, the electrode voltages have not changed since t2, so the signal charge flows into the wells toward the electrode at fH2. One transmission of electrical charge is completed. This action is repeated over and over to execute the horizontal transmissions.

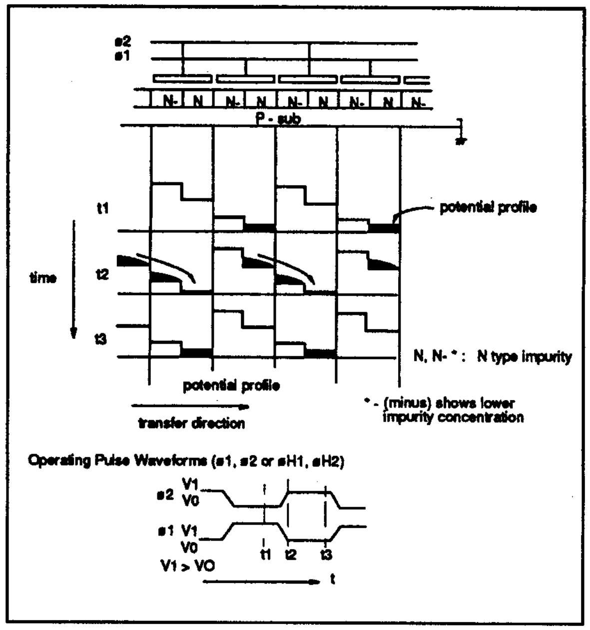


Figure 1

Vertical transfer

The vertical shift register transfers charges using a special two-phase drive mode but the basic transfer principle is the same as horizontal shift register.

1. Discharge Principle of CCD

1.1 Substrate Drain Shutter Mechanism

Normal operation requires the CCD chip to construct an individual potential well at each image cell. The potential wells are separated from each other by a barrier. The barrier is sequentially removed to transfer the charge from one cell to another by pixel clock. This is the basic principle of CCD operation for charge transfer.
The substrate drain vertically moves the charges. When excess potential is applied to substrate underneath each cell, a potential barrier is pulled down to release the charge into the drain. This can happen to all the cells simultaneously, whereas normal CCD shuttering is achieved with a horizontal charge shift to the drain area by interline transferring or reverse transferring of the frame transfer chip.

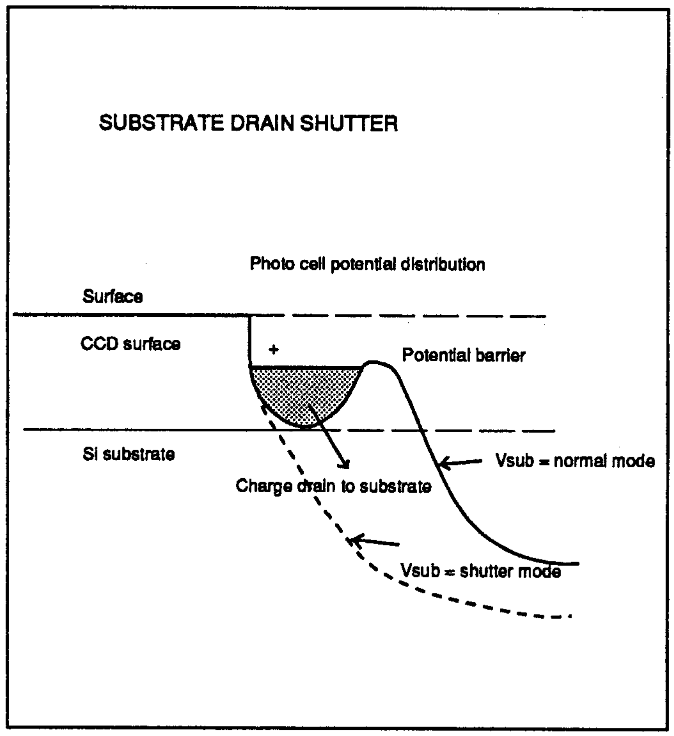
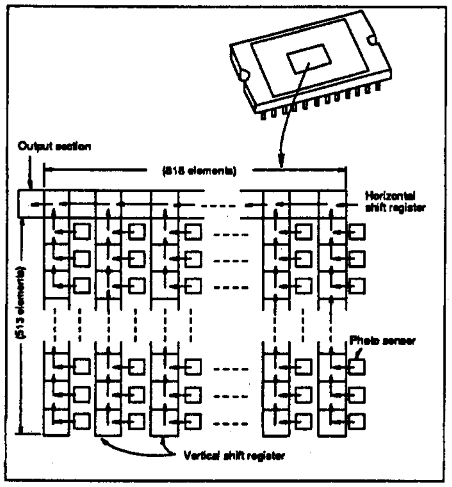
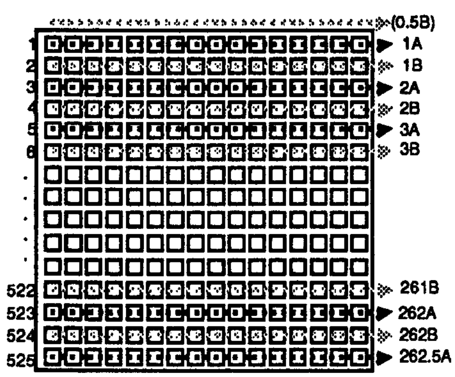


Figure 2

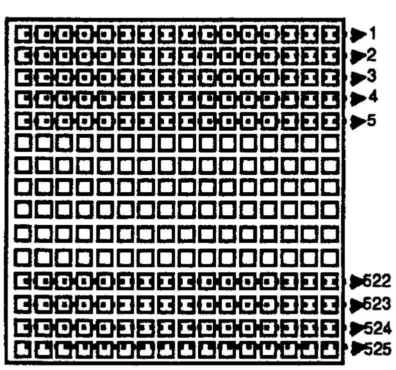
3.3 THE PROGRESSIVE SCAN INTERLINE-TRANSFER ORGANIZATION OF THE CCD IMAGE SENSORS

The TMC-9700 CCD video camera module adopts an progressive scan interline-transfer organization in which the precisely aligned photosensor and vertical transmission section are arrayed interlinearly and scanning of the photosensitive area (pixels) is output sequentially (progressive scan). A horizontal shift register links up with the vertical transmission section. Light variations are sensed by the photosensors which generate electronic charges proportional to the light intensity. The generated charges are fed into the vertical shift registers all at once. The charges are then transferred from the vertical transmission section to the horizontal shift registers successively and finally reach the output amplifier to be read out successively.





INTERLACE SCAN



PROGRESSIVE SCAN

3.4 INSTRUCTIONS FOR POWERING THE TMC-9700

Connectors

The TMC-9700 requires 12 V DC (800mA). Power is obtained through the 12-pin connector located at the rear of the camera. PULNiX offers a 8-conductor power cable with mating connector (model# 12P-02). For digital output, use a 31-pin connector to output 24 bit digital video and other digital sync signal. RGB cable is used for analog RGB and NTSC output. RS-232C cable is also available for the external communication.

Optional output

Each pin of 12 pin connector has to be designated for various options such as clock output, integration control, Async flag output, etc. The customer will be required to assign option numbers.

Warning

The TMC-9700 must use either the 12P Series or C-10 cable. When applying power to the camera, make sure that none of the exposed leads on the multiple conductor cable are touching. This may cause damage to the camera. Besides the power connector, there is a 9 pin RGB video connector on the rear of the camera.

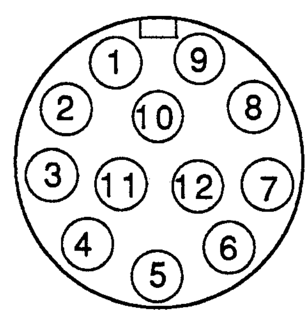
3.4.1 12-PIN CONNECTOR AND POWER CABLES

12-Pin Connector

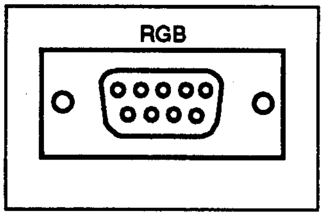
TMC-9700	12P-02 Cable
1. GND	Gray
2. +12V DC In	Yellow
3. N/C	Red Shield
4. N/C (NTSC option)	Red Coax Signal
5. GND	Orange Shield
6. VINIT	Orange Coax Signal
7. VD IN	Black Coax Signal
8. GND	White Shield
9. HD IN	White Coax Signal
10. GND	Brown
11. INTEG CONT / FLAG	Blue
12. GND	Black Shield

Note: Pin #11 is selectable by internal jumper

12-Pin Figure Power Connector



3.4.2 9-pin RGB Connector (D-Sub 9 pin)

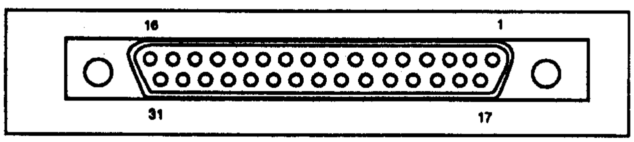


1	GND (C out option)
2	GND
3	R OUT
4	G OUT
5	B OUT
6	N/C (NTSC option)
7	SYNC OUT (Y)
8	GND
9	GND

Compatible with TMC-54GN, XC711,JVC RGB cameras.
Use 50-1050 RGB cable (Y/C output is not available).

3.4.3 31-pin Digital Connector (MP211-031-113-4300)

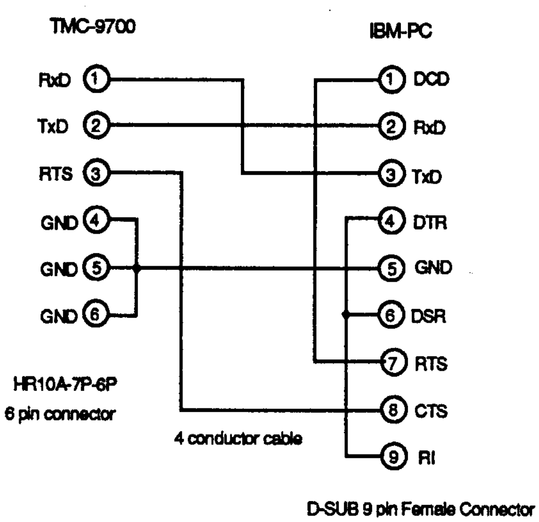
1	RED D0	17	RED D1
2	RED D2	18	RED D3
3	RED D4	19	RED D5
4	RED D6	20	RED D7
5	GRN D0	21	GRN D1
6	GRN D2	22	GRN D3
7	GRN D4	23	GRN D5
8	GRN D6	24	GRN D7
9	BLU D0	25	BLU D1
10	BLU D2	26	BLU D3
11	BLU D4	27	BLU D5
12	BLU D6	28	BLU D7
13	FDV	29	LDV
14	SYNC	30	CLK
15	BLANK	31	GND
16	GND		



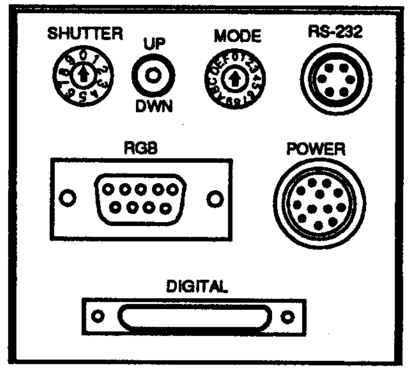
3.4.4 6-pin RS-232C Connector (HR10A-7P-6P)

PC-6P

1	RXD
2	TXD
3	RTS
4-6	GND



3.5 BACK PANEL ASSEMBLY



Mode control switch

0 Auto W/B reset	8 Gamma 0.45 /1
1 Manual Blue adjust	9 PROM factory set
2 Manual Red adjust	A Program page 0
3 LUT gain adjust	B Program page 1
4 Matrix adjust	C Program page 2
5 Edge enhance On/Off	D Program page 3
6 Shutter Internal/External	E Program page 4
7 Sync Interlace/Non-inter.	F Program page 5

4 CAMERA FUNCTIONS

4.1 COLOR BALANCE ADJUSTMENT

The TMC-9700 cameras feature an advanced color balancing system which is controlled by DSP(digital signal processor) and CPU.

4.1.1 White balance

At the power up, the white balance is set by default value which memorized in a program page specified by user (factory set is 3200°K). By selecting mode control 0 and pressing momentary switch, it resets the white balance to white object under certain light condition (teaching). Use white paper in front of the lens and press up/down switch. Do not saturate the image.

4.1.2 R/B Gain

Blue and Red gain is individually adjustable by selecting mode switch 1 or 2. The increase and decrease is controlled by pressing momentary switch to up or down.

4.1.3 Camera Gain

The camera gain is controlled by digital LUT(look up table). Select the mode switch 3 and press momentary switch up or down to change the gain.

4.1.4 Color matrix

The color matrix factor of DSP varies color rendition and reproduction. It can be adjusted by selecting mode 4. See page 10 for the detail.

4.2 OTHER PROGRAMMABLE FUNCTIONS

The TMC-9700 offers user programmable functions with built-in switches and RS-232C communication.

4.2.1 Edge detail enhancement (Sharpness)

Horizontal and vertical edge enhancement is selectable by mode 5.
The DSP mathematically manipulate the horizontal and vertical edge information to sharpen the image.
By pressing momentary switch to up, the function is turned on and with down direction, it is off.

4.2.2 Gamma selection

The gamma function is selectable between 0.45 (default) and 1.0 (linear output).
Select the mode 8 and press momentary switch UP (0.45) or DOWN(1.0).

4.2.3 Shutter selection

The TMC-9700 shutter function is identical to TM-9700 which provides internal normal shutter and asynchronous shutter with external trigger (VINIT). The each mode is selectable up to 1/16000 sec.
It also accepts the double pulse shutter speed control which user can control the speed by providing two pulses with certain duration.
See the detail operation in page 11.

Shutter Control Switch

	Manual shutter mode	Async reset mode	
0	no shutter	no shutter	
1	1/125	1.0H	1/16000
2	1/250	2.0H	1/8000
3	1/500	4.0H	1/4000
4	1/1000	8.0H	1/2000
5	1/2000	16 H	1/1000
6	1/4000	32 H	1/500
7	1/8000	64 H	1/250
8	1/16000	128H	1/125
9	N/C	Shutter determined by pulse width	

Mode 0:	Normal mode
Mode1-4:	Fast mode
Mode5-8:	Slow mode
Mode 9:	Pulse width control mode

4.2.4 Video output Scan and Sync selection

The TMC-9700 scans progressively at CCD and processed through DSP and frame memory. The output is however, selectable for interlace (RS-170 RGB) or non-interlace.
The analog output is RGB interlace or non-interlace selectable. The digital output is selectable also.
By selecting mode 7, it changes between 2:1interlace (Up) and non-interlace ..progressive (Down).

4.2.5 User parameter set and back up

There are 6 pages of EEPROM memory back up in order to store user parameters.
By selecting each page (mode switch A through F) and pressing UP of momentary switch makes TMC-9700 write the data and memorizes the data into EEPROM.
By pressing DOWN makes it display the data (Read).

For example, after adjusting various parameters by selecting modes from 1 through 8, user can select the page (PROM space) to store then press UP. The data currently displaying is saved.
When the same data is required after power up or after changing parameters, user can simply recall the data by selecting the page and pressing DOWN.

4.2.6 Black level (set up) control

The TMC-9700's DSP has the black level control and the factory set is calibrated at 3200°K color temperature. When the white balance is conducted and lens is closed, black level R,G,B outputs are calibrated to be the same.
An user can calibrate the black level at certain lighting condition by using RS-232, flare offset control.
First, adjust the white balance under the specific lighting condition and use RS-232 command D. Select black reference enabled and use the flare offset control for R, G, B channels.

EEPROM factory set

User parameters can be stored in EEPROM by selecting the mode switch from A through F and pressing the momentary switch Up.
In case the original factory set value is required, user can recall the page 9 by powering up while up/down switch is kept up. The factory default is loaded but cannot be changed by user.

RS-232C external communication

The TMC-9700 is capable to communicate with external control unit via RS-232C.
The communication overrules preset data of memory pages and back panel switches.

For the detail, please refer page 13.

5 TMC-9700 MODE CONTROL

Mode sw.: 0 Auto white balance trigger

By selecting 0 position of the mode switch, internal white balance triggering is implemented.

1. Set shutter switch 0 (no shutter)
2. Set mode switch 0.
3. Place white object (white paper) in front of camera.
4. Press Up/Down switch(up or down). It triggers the balance.

Note: the white balance data can not be stored in EEPROM. Once the power is off, it requires new white balance at next power up.

Mode sw. : 1 through 3 External white balance

By selecting 1 through 3 position, user can set independent white balance data for Blue (log(B-G)), Red (log(R-G)) and Manual gain.

1. Set mode switch to 1.
2. Press Up/Down switch to increase or decrease the Blue gain.
3. Set mode to 2. and repeat above for Red gain.
4. Set mode to 3 and repeat process 2 for over-all gain of LUT (look up table).

Mode sw.: 4 Matrix selection

This mode selects the preset matrix of four modes.

1. Set mode switch to 4.
2. Press Up/Down switch to select following modes
   - A: Improved Matrix...Higher chrominance
   - B: 2 x Matrix....Two times of illuminance
   - C: Unity Matrix....Normalized matrix
   - D: Default Value....DSP default (factory set)

Each time Up is pressed, it moves from A to D, at each time Down is pressed it moves from D to A.

Mode sw.: 5 Edge enhancer On/Off

Both horizontal and vertical edge enhancer (sharpness control) is turned on or off.

1. Set mode switch to 5.
2. Press Up switch to turn On the edge enhancement.
   Press Down to turn Off the enhancement.

Mode sw.: 6 Shutter mode selection

It selects Internal shutter mode / Async shutter mode.

1. Set Mode switch to 6.
2. Press Up to select Internal shutter.
   Press Down to select Async shutter .

Mode sw.: 7 Video output scanning mode

The RGB video signal is output with 2:1 interlace (Odd + Even field at 59.94 Hz field rate and 525 lines / frame) or Progressive scan (Non-interlace 525 lines / 30 Hz frame rate).

1. Set Mode switch to 7.
2. Press Up switch to select 2:1 interlace.
   Press Down switch to select Progressive scan.

Mode sw.: 8 Gamma correction

By selecting this switch, gamma correction is changed between Gamma = 0.45 (On) and Gamma = 1.0 (Off).

1. Set Mode switch to 8.
2. Press Up switch to select Gamma On (0.45).
   Press Down switch to select Gamma Off(1.0).

Mode sw.: 9 Factory default and Freeze mode

When mode switch is set to 9 and keep pressing momentary switch up then power up, it recalls factory default data.
While power is on and select #9 and press down activate ENINT (freeze mode). Press up changes it to free run.

Mode sw.: A through F
Write page (Save) and Read page (Load)

By selecting this mode, it saves the data into back up memory page or loads the data from the memory.

1. Set Mode switch to A through G (any page).
2. Press Up switch to write (Save).
   Press Down switch to read (Load).

Note: The TMC-9700's internal CPU refers the start up data at the power up which stored in the 6 pages (A - F). User can set the page (A - F) at power up for the initialization. When the mode switch is set to 0 through A at power up, it loads data of page A (user default page). If the initial set up selects B through F, it loads the specific page data.
Each page is programmable by user on following parameters.
Data selected by mode switches from 1 through 8.

1. External white balance data
2. LUT gain data
3. Matrix data (120 bit)
4. Edge enhancer: On/Off
5. Shutter mode: Internal/Async
6. Video scanning: 2:1 interlace/Progressive
7. Gamma: 0.45/1.0

Example 1: Save parameters to page B.
Shutter: Async
Scan: 2:1 interlace
Gamma: 1.0

After power up, select shutter switch 0 then,
1. Set Mode switch to 6. and press Down (Async).
2. Set Mode 7 and press Up (2:1 interlace).
3 Set Mode 8 and press Down (gamma = 1)
(Above setting can be done in any order)
4. Set Mode switch to B and press Up (Save).

In order to confirm the data, user can load the data by pressing Down at the selected page.

Example 2: Load data from previous setting and change some parameters and save in another page. Then, change the scan mode of page C from progressive to interlace and save in page F.

1. Power up with mode switch C or if power is on, select mode C and press Down to load page C.
2. Set Mode 7 and press Up (Interlace).
3. Set Mode F and press Up (save into page F).

6 ASYNCHRONOUS RESET FULL FRAME SHUTTER CAMERA OPERATION

The TMC-9700 is designed to accommodate an ON-LINE inspection reset mechanism with full frame shutter. It takes external horizontal sync to lock the camera and VINIT pulse for resetting the camera asynchronously. The shutter speed can be controlled by either an external double pulse or internal shutter speed control with a 10-position dial switch on the back panel.

6.1 Asynchronous shutter

For Async Shutter mode, select mode sw.6 and provide external Hd for phase locking. When the negative going reset pulse (VINIT) is applied, the camera will latch the falling edge to its next horizontal drive and reset vertical sync timing immediately. Therefore, the horizontal phase won't be interrupted. The TMC-9700 asynchronous camera outputs a full frame of shuttered video in progressive or interlace format from a frame buffer. The frame buffer is updated upon receiving negative reset pulse. Analog RGB(RS-170) and 24-bit digital (TTL) outputs are available.

6.2 Shutter Speed Control

6.2.1 External pulse width control mode

For External Pulse width control Mode, set dial switch to "9". Apply a VINIT signal with controlling pulse width, which can be generated from an external event trigger to the camera. and the internal reset pulse will be latched to Hd. The duration from the first VINIT pulse leading edge to rising edge, X controls the shutter speed as follows:

Shutter speed ts = X + 9H - 18H ;

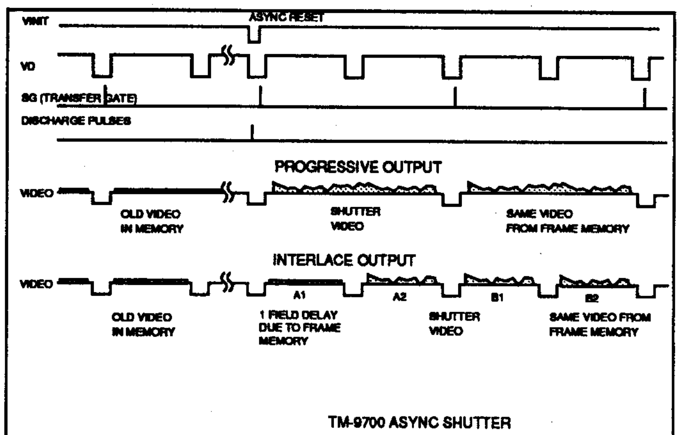
1H = 63.5 μsec;
Min. duration (X) = 10H; Min. pulse width = 2H.

Eg., The fastest speed is given when the pulse width is set at 10H from the leading edge, the shutter speed is 63.5μsec (10H+9H-18H) or 1/16000 sec.
For 1/1000 sec shutter (1ms = 16 H), set the pulse rising edge at 25H from the leading edge (falling edge) (25H+9H-18H =16H).

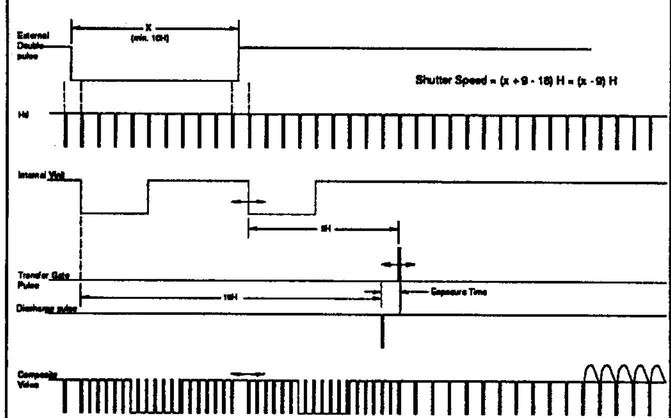
One frame of video output will start from the rising ledge for progressive format. For interlace format, there is one field delay due to frame memory (one frame pair is Odd and Even pair). The camera will output same video from memory when VINIT is kept high (5V) and update the image upon receiving next set of double pulse.

Long Integration
With pulse width control, long integration is possible up to a few second besides integration control (pin #11 of 12-pin connector). TMC-9700 internal memory can capture the integration image and freeze. See mode selection #9.

Async output
TMC-9700 has two sets of sync generator. When it is running with interlace mode, the output is continuous regardless async reset of image capturing. When it is progressive mode, the output is asynchronous and there is no time delay.



TMC-9700 async shutter



Pulse width control

6.2.2 Internal Fast reset mode

For Internal Fast Reset Mode, set 10-position dial switch from "1" to "4". When fast reset mode is selected, the camera resets with internal VINIT timing, which is latched to Hd, and video output is also synchronized with internal VINIT timing without further delay. The shutter speed is controlled by the dial switch.

6.2.3 Internal Slow reset mode

With the Internal Slow Reset mode selected, the camera operates the reset and shutter in the same means as the wide pulse width control mode. When external VINIT pulse is applied, internal VINIT is latched to Hd and the second internal VINIT signal is generated to set up the shutter speed period. The shutter speed is controlled by setting the dial switch from "5" to "8". Video output timing starts right after the second internal VINIT.

6.3 FRAME MEMORY

The TMC-9700 has a built-in frame memory in order to convert progressive scanning images to RS-170 interlace or non-interlace scanning images. This feature provides the following advantages:

1. Asynchronously captured images are output as standard continuous video signals so that a normal monitor or frame grabber can display or process without special asynchronous video grabber.

2. Integration video is continuously output until the next capture. Normally, the camera cannot output the video signal during the integration, and the periodic integration causes blinking of video signal. The TMC-9700 memory keeps the stored image until the next image is completed so that there is no blank interval during integration.

3. Digital format of the video output can be used as direct interface with computer. The format is interlace or progressive.

How to activate the frame memory.

6.3.1 Asynchronous reset mode (Select mode selection switch)

When External VINIT is high (5V), the TMC-9700 expects the async pulse input. It resets at the negative going pulse edge and captures the frame regardless of the shutter speed (fast or slow mode). The video is kept and output continuously during VINIT high. When the next VINIT pulse comes in, the next image is captured. If the mode selection is manual shutter mode, the video output is real time. Because of the progressive scan to interlace scanning, the interlace video reacts slower to moving objects than with normal interlace cameras. (It converts 30 Hz frame into 60 Hz rate and since moving objects are captured at a slow rate, 60 Hz scanning cannot show faster motion.)

6.3.2 Integration

The TMC-9700 is capable to integrate for longer exposure and the video output is read from the frame memory. The control of the integration is done with INTEG CONT (11 pin of 12-pin connector). While INTEG CONT is kept low, the camera keeps integrating and upon the logic going to high, it captures the integrated image into the frame memory. By activating ENINT(Freeze mode) of #9 mode selection and pressing up/down switch down, the video output maintains the same frame until the next image is captured with new pulse.

7 PROGRESSIVE SCANNING

Standard TV system scanning is 525 line interlace scanning as specified in RS170. Every other horizontal line (ODD lines and EVEN lines) are scanned at a 60 Hz rate per field, and completes scanning with two fields (one Frame) at 30 Hz rate. Because of the interlace scanning, vertical resolution of CCD cameras is limited at 350 TV lines regardless of horizontal resolution. When electronic shutter is applied, the CCD can hold only one field of charge at each exposure. Therefore, the vertical resolution of the electronic shutter camera is only 244 TV lines.
The TMC-9700 uses a state-of-the-art CCD called a "Progressive scanning interline transfer CCD" which scans all lines sequentially from top to bottom at one frame rate (30 Hz). Like a non-interlace computer screen, it generates a stable crisp image without alternating lines and provides full vertical TV resolution of 484 instead of 350.
The interline transfer architecture is also important to generate simultaneous shuttering. This is different from full frame transfer architecture which requires a mechanical shutter or strobe light in order to freeze object motion.

The TMC-9700 outputs the progressive scanned image with electronic shutter in three different formats:

7.1 Progressive scanning digital and analog output

The CCD signal goes through A/D and D/A converters. The frame memory is capable of capturing async and integration video without having special frame grabbers. By selecting mode switch 7 to progressive scan, the video output is non-interlace scanning on both analog and digital outputs.
The RGB analog outputs are the same as 75Ω, 0.714Vp-p format at 30Hz rate available from 9-pin connector.
The 24-bit digital output is available from 31-pin connector with TTL format.

7.2 Interlace scanning output (Digital and Analog)

By setting the mode switch 7 on the back plate to 2:1 interlace mode, the TMC-9700 outputs normal RS-170 video for standard RGB color monitor display or general purpose video frame grabbers.
Since the interlace mode must use a frame memory, it can output captured images of async and integration video.

7.3 NTSC or Y/C analog output (optional)

While the digital output is the same as 7.2, the analog output can be encoded to NTSC or Y/C output.
The NTSC output is available from a standard RGB cable but Y/C requires a special cable.

8 TMC-9700 RS-232C CONTROL

The TMC-9700 can be controlled its built-in microcomputer chip (CPU) by external RS-232C interface. The internal CPU controls TMC-9700 operation mode and DSP parameter changes.

8.1 RS-232C communication default condition

Parity :	None
Data :	8 bit
STOP :	2 bit
Baud rate :	9600 bps

(If other communication condition is required, please contact PULNiX.)

8.2 RS-232C command

The TMC-9700 command packet starts with STX (Start of Text = 02H) and then followed by Command Code (C.C. .....one alphabet) , Command option parameter and ETX (End of Text = 03H) to end.
One packet is 8 bit ASCII code.
When a packet is received by TMC-9700 (ETX:03H is detected), it reads internal packet of the receiver buffer. If it is the correct packet then it processes the parameters based on the command. When the process is completed, it sends a completion signal (AK packet). If an error is detected, No-go signal (NK packet) is sent back and disregards the packet signal in the buffer. When NK packet is sent from TMC-9700, the host must correct the error and resend the packet.

Example: Executing Auto-white balance
In order to set auto-white balance sampling, The C.C. packet is sent as follows,
STX, "W", "I", ETX
02H,57H,49H,03H
where "W".....white balance command mode
"I".......Internal
The TM-9700 will send back
STX,ACK,ETX or STX,NAK,ETX
02H,06H,03H .02H,15H,03H

8.3 Command W

Function: White balance Internal / External selection

White balance internal mode: white balance sampling starts at trigger (Auto white balance).
White balance external mode: Gain, B-G, R-G parameters are set.

TMC-9700's white balance consists Internal mode and External mode.

External mode: It controls DSP for Gain, log(R/G), log(B/G).
Internal mode: Under certain lighting condition, it can set the white balance to a reference white. (white color teaching). Apply white material in front of the camera and trigger the white balance.

The DSP samples 64 blue pixels and 64 red pixels inside window of center region and calculates logB - logG, logR - logG to decide R and B balance.

Note:
It holds the data until next triggering.
The white balance data is not kept in backup memory. Once the camera power is off, it requires new white balance at power up.

White balance Internal mode and trigger:
STX,"W", "I", ETX
02H, 57H, 49H, 03H

External mode and set Gain, B/G, R/G values to DSP:
STX, "W", "E", "0 8", "E 0", "E 8", ETX
02H, 57H, 45H, 30H, 38H,45H, 30H, 45H, 38H, 03H

8.4 Command K

Function:: Gamma function On / Off
ON = 0.45, Off = linear

Gamma = 0.45 (On) — STX, "K", "0", ETX
02H, 4BH, 30H, 03H

Gamma = 1 (Off) — STX, "K", "1", ETX
02H, 4BH, 31H, 03H

8.5 Command M

Function: DSP matrix selection for External program mode / Unity mode.

Unity Mode: It uses internal default parameter. It can not be controlled externally.
External program Mode: DSP can be controlled by external command.

Unity Matrix set: — STX, "M", "1", ETX
02H, 4DH, 31H, 03H

Ext. Program mode: — STX; "M", "0", ETX
02H, 4DH, 30H, 03H

8.6 Command E

Function: Edge Detail Enhancement (Sharpness or Aperture control) On / Off.
DSP selects horizontal and vertical edge detail On or Off.

No enhancement (Off): — STX, "E", "1", ETX
02H, 45H, 31H, 03H

Enhancement On: — STX, "E", "0", ETX
02H, 45H, 30H, 03H

8.7 Command O

Function: Scanning selection of 2:1 interlace output or progressive scan output (Non-interlace).

Interlace output: — STX, "O", "1", ETX
02H,4FH, 31H, 03H

Progressive scan: — STX, "O", "0", ETX
02H, 4FH, 30H, 03H

8.7 Command N

Function: TMC-9700 shutter mode selection. It selects ASYNC shutter mode or Internal shutter mode.

ASYNC shutter mode: STX, "N", "1", ETX
02H, 4EH, 31H, 03H

Internal shutter mode: STX, "N", "0", ETX
02H, 4EH, 30H 03H

TMC-9700 has two sync generators inside, for CCD drive and signal output. Based on the shutter mode, the signal output sync generator creates synchronized signal with external sync (HD, VD) and video memory read out sync.

In interlace output mode, the CCD driver sync generates a CCD transfer pulse during Even field timing and the video output of the progressive scan CCD is scan-converted into Odd / Even pair of interlace signal through the frame memory.
At ASYNC mode, the CCD driver side is reset asynchronously by external Vinit pulse, but the signal output sync stays synchronous to RS-170 video output.

When progressive scan mode is selected, there is no field delay and the output is asynchronous (no continuous output).

8.9 Command D

Function: DSP (RGB processor) operation control and Matrix selection

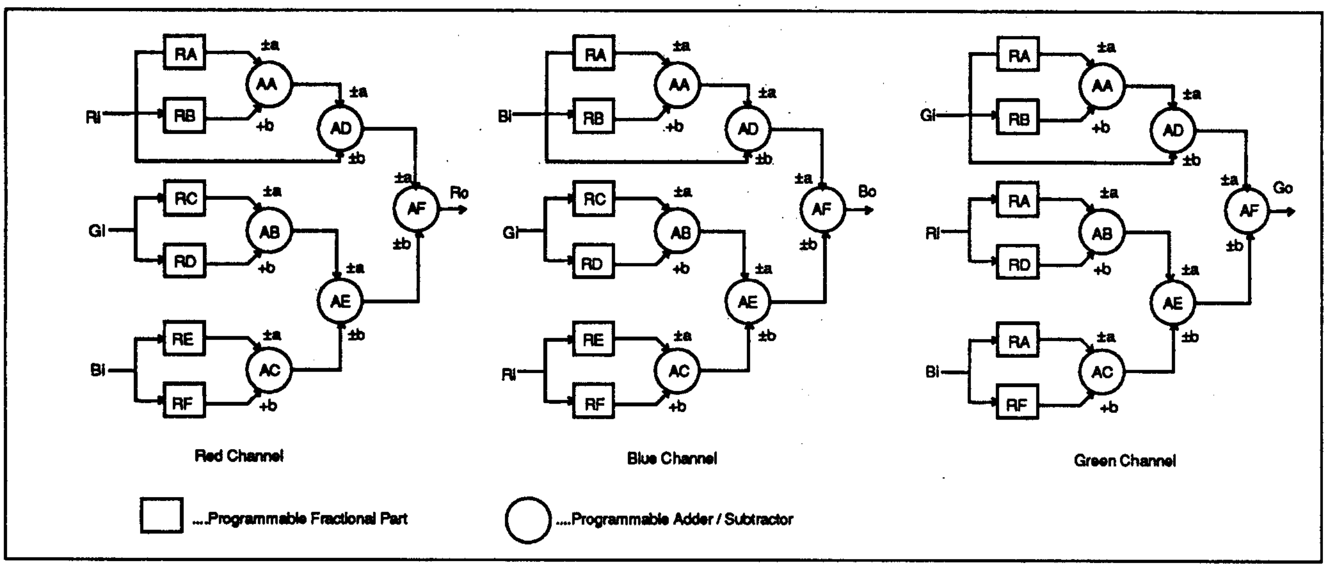
DSP control STX, 'D', Table 1 (120 character), ETX
02H, 44H, ... , 03H

Color matrixing is an operation designed to improve the color rendition and color saturation of the image. The matrixing corrects the spectral sensitivities of the image sensor for the chromaticities of the display. This significantly improves the subjective quality of the image, since it allows the tone and color reproduction to be optimized, which also improves the apparent contrast and sharpness of the system.
The mathematical transformation is a linear space 3 x 3 matrixing operation as shown in Eq. 1

$$\begin{vmatrix} Ro \\ Go \\ Bo \end{vmatrix} = \begin{vmatrix} 1.75 & -0.25 & -0.5 \\ -0.1875 & 1.3125 & -0.125 \\ -0.125 & -0.5 & -1.625 \end{vmatrix} \begin{vmatrix} Ri \\ Gi \\ Bi \end{vmatrix}$$

Eq. 1

The coefficients have been optimized for the spectral sensitivities of a certain CFA (color filter array).
For camera systems, a linear-space color correction matrix is used. The coefficients are programmable through the serial interface (RS-232C) in the format shown in Table 1. A wide range of matrix coefficients can be programmed in discrete steps.
The matrix can be by-passed by setting "MTRX_DISB" = 1. This sets up a unity matrix The programming of the matrixing is determined in conjunction with Fig.1. Each fractional (FR) part can be programmed to be 0, 1, 1/2, 1/4, 1/8, 1/16, 1/32 or the default value of input. The adders can also be programmed to have certain inputs ±.
If both inputs must be negative to realize the coefficient, then both should be made positive and the next adder that the result goes to should be made negative at the input. Also the rows of the matrix should sum to unity for appropriate gray scale performance. The programmability is achieved by shifting in the appropriate coded bit stream as shown in Table 1.



The DSP control command is software driven to ease the control.
The TMC9700P software provides menu driven command control for two DSPs.

8.9.1 Color matrix
Current color matrix is preset to 4 types.
Select current setting and white balance.
The software selects the same matrix as the back panel switch #4 described in page 10.
This is controlling the DSP A240.
If user needs to set different RGB matrix, it must be sent by D command of RS-232 communication.

8.9.2 White balance
White balance is controlled in the DSP A240.
The menu "current setting, white balance" indicates internal and external balance. The internal is automatic white balance which the DSP calculates green gain and B/G, R/G offset to white signal. The final value is not readable since it is inside of DSP.
The external control is manual control to vary green gain and B/G, R/G offset.
Use a white material in front of lens and adjust the level so that it is not saturating and set internal white balance which is the same function as rear panel momentary switch. When it is manual, select the adequate combination of the balance values.

8.9.3 Black level control
Make sure the black reference clamp is enabled in "current setting" and "black reference clamp".
In the main menu, select #7. Control A240 RGB-DSP.
(Note: Do not alter any of #6. A110 CFA-DSP parameters. These are specific parameters to TMC-9700 imager and peripheral components.)
The black level control is only implemented by RS-232 command of this program.
"Input LUT" must be enabled.
"Black level offset" must be enabled.
After completion of white balance, Close the lens and observe R,G,B output level. Since white balancing requires gain changes for each R, G, B channel, it is normal to see slight unbalance of the black level setup.
Select flare offset and adjust each values of R, G, B.
The result of offset change can be observed at analog RGB output.

Save the data in page A as user default since it is not controllable by rear panel switches.

8.9.4 Edge enhancement
The edge enhancement is the other function of the DSP.
This is accessible by RS-232 as well as rear panel switch.
Select "current setting" and "edge enhancement" to enable or disable the function.

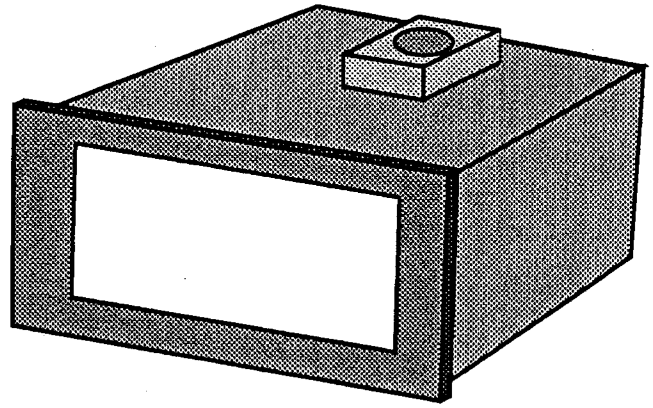
Table 1. DSP MATRIX

0	Dummy	
0	Horizontal Edge detail	0 = Yes (default), 1 = No
0	Vertical Edge detail	0 = Yes (default), 1 = No
0	Horizontal Edge filter	0 = -1,2,-1 (default), 1 = -1,0,2,0,-1
0	Detail Boost factor	0 = 1x (default), 1 = 2x
00	Detail LUT page (a8, a7)	00 = page 0 (default), 01 = pg1, 10 = pg2, 11 = pg3
0000000	7 bit address within page for fixed offset i.e 3 x 4 matrix MSB to LSB	
0	Edge detail / fixed value above address	0 = edge detail (default)
0	Red AF ± a	0 = +a (default), 1 = -a (ADout)
1	Red AF ± b	0 = +b (default), 1 = -b (AEout)
0	Red AE ± a	0 = +a (default), 1 = -a (ABout)
1	Red AE ± b	0 = +b (default), 1 = -b (ACout)
0	Red AC ± a	0 = -a (default), 1 = +a (RF ± RE)
110	Red RF(BLU_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, -11 = 1/32
111	Red RE(BLU_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
1	Red AB ± a	0 = -a (default), 1 = +a (RD ± RC)
001	Red RD(GRN_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
111	Red RC(GRN_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
0	Red AD ± a	0 = +a (default), 1 = -a (AAout)
0	Red AD ± b	0 = +b (default), 1 = -b (1x)
0	Red AA ± a	0 = +a (default), 1 = -a (RB ± RA)
110	Red RB (RED_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
101	Red RA (RED_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
101	Blu RA(BLU_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
011	Blu RB(BLU_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
0	Blu AA ± a	0 = +a (default), 1 = -a (RB ± RA)
0	Blu AD ± b	0 = +b (default), 1 = -b (1x)
0	Blu AD ± a	0 = +a (default), 1 = -a (AAout)
101	Blu RC (GRN_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
001	Blu RD (GRN_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
1	Blu AB ± a	0 = -a (default), 1 = +a (RD ± RC)
011	Blu RE (RED_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
001	Blu RF (RED_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
0	Blu AC ± a	0 = -a (default), 1 = +a (RF ± RE)
0	Blu AE ± b	0 = +b (default), 1 = -b (ACout)
1	Blu AE ± a	0 = +a (default), 1 = -a (ABout)
0	Blu AF ± b	0 = +b (default), 1 = -b (AEout)
0	Blu AF ± a	0 = +a (default), 1 = -a (ADout)
0	Grn AF ± a	0 = +a (default), 1 = -a (ADout)
0	Grn AF ± b	0 = +b (default), 1 = -b (AEout)
0	Grn AE ± a	0 = -a (default), 1 = +a (ABout)
0	Grn AE ± b	0 = +b (default), 1 = -b (ACout)
0	Grn AC ± a	0 = -a (default), 1 = +a (RF ± RE)
001	Grn RF (BLU_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
111	Grn RE (BLU_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
0	Grn AB ± a	0 = +a (default), 1 = -a (RD ± RC)
001	Grn RD (RED_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
010	Grn RC (RED_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
0	Grn AD ± a	0 = +a (default), 1 = -a (AAout)
0	Grn AD ± b	0 = +b (default), 1 = -b (1x)
0	Grn AA ± a	0 = +a (default), 1 = -a (RB ± RA)
010	Grn RB (GRN_IN) (c,b,a)	000 = default, 001 = zero, 010 = 1/16, 011 = 1/32
111	Grn RA (GRN_IN) (c,b,a)	continued 100 = 1x, 101 = 1/2, 110 = 1/8, 111 = 1/4
00000000	Grn Flare Offset MSB to LSB	
00000000	Blu Flare Offset MSB to LSB	
00000000	Red Flare Offset MSB to LSB	

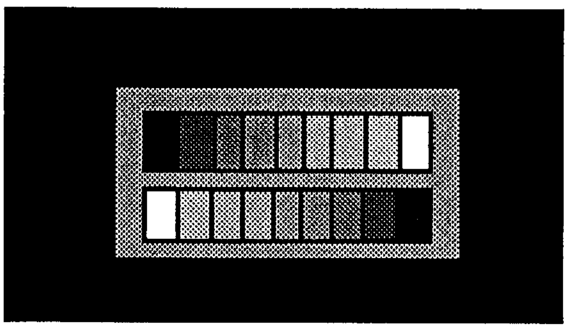
9 ALIGNMENT AND ADJUSTMENT

9.1 EQUIPMENT

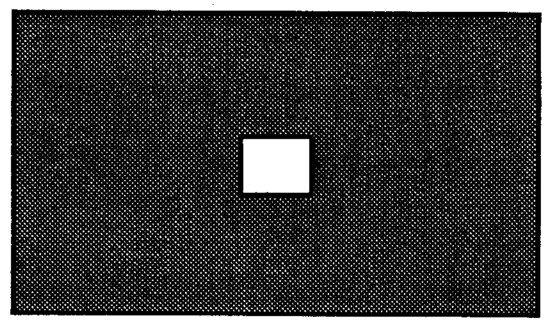
1. Light source for test chart.
   Pattern Box PTB-100 (90-130V)
   PTB-220 (190-240V)



2. For video level and gamma adjustment.

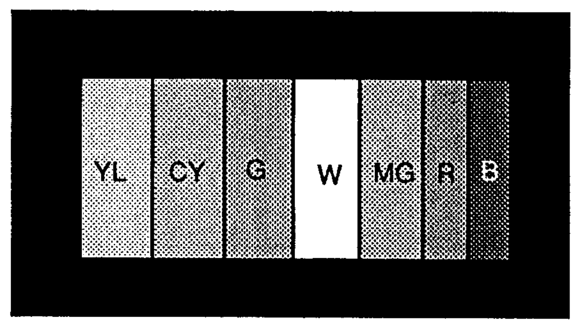


Grayscale Chart



White Window Chart

3. For color adjustment.
   (Use color bar chart and Macbeth Colorchecker chart)



Color Bar Chart

4. For signal adjustment.
   Vectorscope / Waveform monitor
   Oscilloscope
   Kodak color filter; No.25 red, No.56 green,
   No.47B blue

5. Standard Pattern Frame

9.2 PREPARATION

9.2.1 BACK FOCUS ADJUSTMENT

Subject: Resolution chart

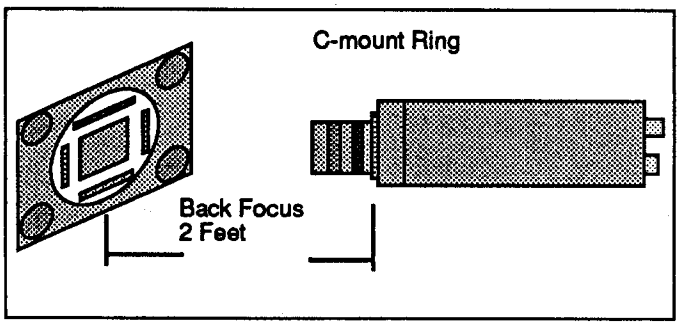
1. Mount the manual lens (i.e. Cosmicar 25mm, F=1.4).

2. Open the lens iris completely and set lens focal length to minimum for the lens used (e.g. 2 ft.).

3. If image is not focused properly, set back focus as follows.

4. Unscrew the M2x3 hex screw on the Front Panel until the focus ring is loose.

5. Adjust the silver back focus ring until the image is focused.
6. Repeat steps 4 and 5 if needed.



4.2.1 PRESET

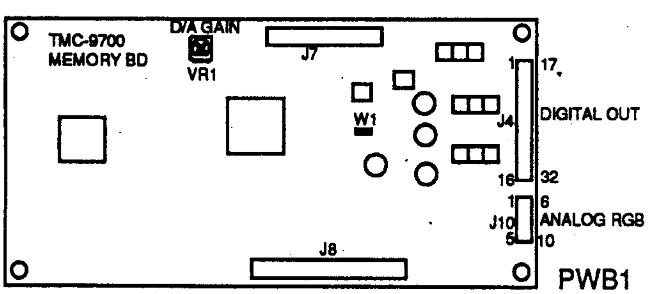
Preset each potentiometer as follows:

PWB Imager
Follow TM-9700 imager adjustment procedure for Vsub and RG level.
VR2 (Vsub) is calibrated with light source to minimize the blooming.
VR1 (RG) is set at the mechanical center.

PWB1 (Memory board)

W1	Sync out select	Left; 2:1 interlace (std) Right; non-interlace
VR1	D/A output gain	Preset at 1.6 ± 0.1V and calibrate at RGB

output (R8,11,14) resistors to be 714 mV at saturation.

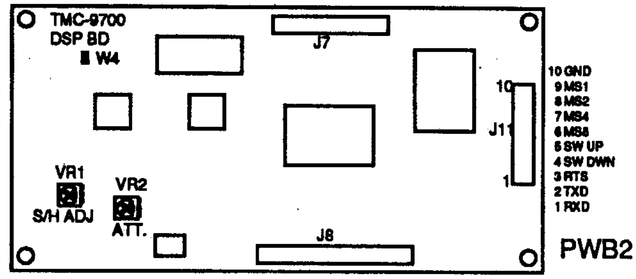


PWB1

PWB2 (DSP board)

W4	CDS select	Open for CXA-1399 Short for CXA-1439
VR1	A/D S/H adjust	Preset at mechanical center
VR2	Attenuation adj.	Do not use

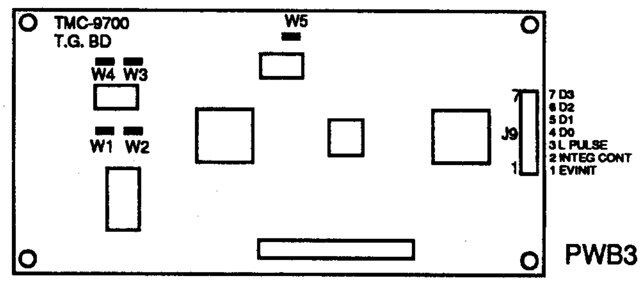
W1, W2, W3 Open



PWB2

PWB3 (T.G. board)

W1	SHD	Right
W2	SHP	Right
W3	RG	Open
W4	RG	Left
W5	CL1	Left

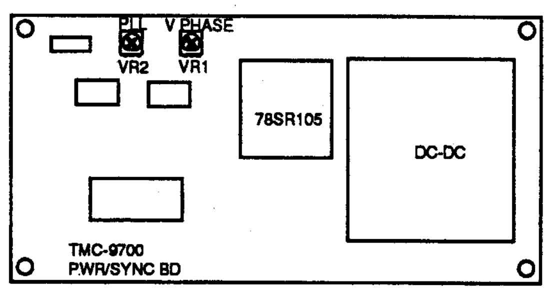


PWB3

PWB4 (Power/sync board)

VR1	V phase	Preset at mechanical center
VR2	PLL	Preset at mechanical center

See standard PLL adjustment procedure.



PWB4

9.3 CALIBRATION AND ADJUSTMENT
With above settings, the camera will output a good picture and you can proceed to the fine tuning process.

9.3.1 A/D S/H timing
Equipment: Color bar chart (3200°K), Oscilloscope , RGB color monitor.

Remove the color bar chart and place No.25 red filter in front of the camera.
Probe pin #8 of CXA-1399.
(Adjust VR1 of BWB2 (DSP board) so that the red signal is maximum level.)... Use internal default and do not use this procedure unless specified.

9.3.2 RGB output level
Probe each R, G, B output (with 75 Ω termination) and adjust VR1 of PWB1 so that the video level is 0.714 ± 0.02 V. R8, R11, R14 can be used to probe.

9.4 FUNCTION TEST

9.4.1 Back panel switches

1. Select mode #0 (auto white balance) and press up. Make sure the white balance is set. Suggest to use a white paper in front of the camera. Do not saturate.

2. Select mode #1 (Blue gain)
Press up or down and check the blue gain changes.

3. Select mode #2 (Red gain)
Press up or down and check the red gain changes.

4. Select mode #3 (Over-all gain)
Press up or down and check the over-all gain changes.

DSP gain is set by the digital numbers (8-bit).

-127	←	0	→	+127
80H		00		7FH

Each digital number reflects 0.2 dB/step.

5. Select mode #4 (Color matrix)
Find matrix changes with up switch.

Matrix A	1.75	-0.25	-0.5
(Improved	[-0.1875	1.3125	-0.125]
matrix)	-0.125	-0.5	1.623
Matrix B	2	0	0
(2X Matrix)	[0	2	0]
	0	0	2
Matrix C	1	0	0
(Unity Matrix)	[0	1	0]
	0	0	1
Matrix D	1.625	-0.25	-0.375
(DSP default)	[-0.625	1.3125	-0.25]
	-0.03125	-0.5	1.53235

6. Select mode #5 (Edge enhancer)
Press up for the enhancer ON and press down for OFF.

7. Select mode #6 (Interlace/non-interlace)
Press up for interlace output and press down for non-interlace output.

8. Select mode #7 (Gamma selection)
Press up for the gamma = 0.45 and press down for 1.0.

9. Select mode #9 (Freeze)
Press down for enabling ENINT to freeze image and press up for free run.

10. Select page A and save the data by pressing up. Change some parameters and select A again and press down to recall previous data.

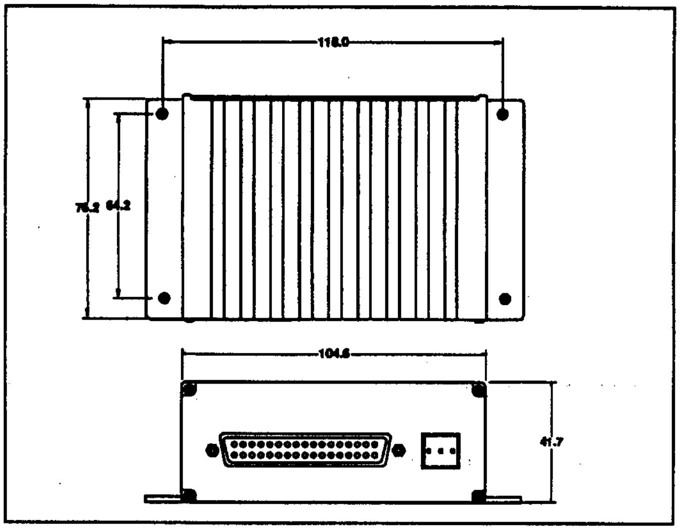
9.4.2 RS-232C control and calibration

Connect RS-232C cable to computer output.
Use TMC-9700 software and type:TMC9700P.
Follow the menu and instruction on the screen.
The software has report function from the camera to indicate setting value of each parameter.

10 ACCESSORIES

10.1 RS-422 INTERFACE

10.1.1 RS-422 INTERFACE MODULE



37-pin and 62-pin connector pin configurations

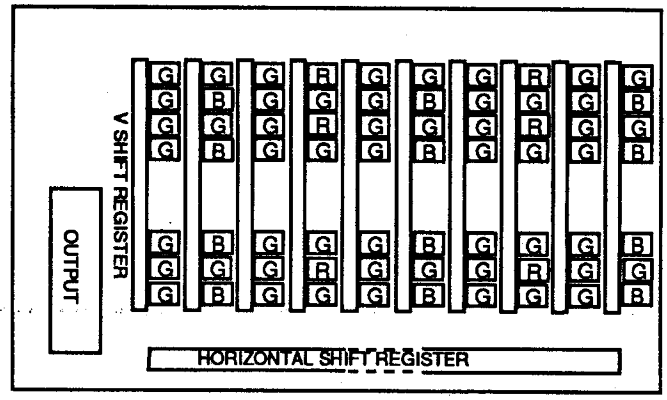
37-pin Dsub (30DGC-02)		62-pin HDsub			
RD0	1	RD0+	20	RD0-	41
RD1	20	RD1+	35	RD1-	40
RD2	2	RD2+	18	RD2-	39
RD3	21	RD3+	17	RD3-	38
RD4	3	RD4+	16	RD4-	37
RD5	22	RD5+	15	RD5-	36
RD6	4	RD6+	14	RD6-	35
RD7	23	RD7+	13	RD7-	34
GD0	5	GD0+	12	GD0-	33
GD1	24	GD1+	11	GD1-	32
GD2	6	GD2+	10	GD2-	31
GD3	25	GD3+	9	GD3-	30
GD4	7	GD4+	8	GD4-	29
GD5	26	GD5+	7	GD5-	28
GD6	8	GD6+	6	GD6-	27
GD7	27	GD7+	5	GD7-	26
BD0	9	BD0+	4	BD0-	25
BD1	28	BD1+	3	BD1-	24
BD2	10	BD2+	2	BD2-	23
BD3	29	BD3+	1	BD3-	22
BD4	11	BD4+	43	BD4-	44
BD5	30	BD5+	45	BD5-	46
BD6	12	BD6+	47	BD6-	48
BD7	31	BD7+	49	BD7-	50
CLK	33	CLK+	59	CLK-	60
LDV	32	LDV+	57	LDV-	58
FDV	13	FDV+	51	FDV-	52
SYNC	14	SYNC+	53	SYNC-	54
BLNK	15	BLNK+	55	BLNK-	56
		GND (digital GND)			21
GND	16-17,34-37	+5V IN	62	GND	61

(Do not supply 5V if 12V is used)

11 IMAGER COLOR FILTERS

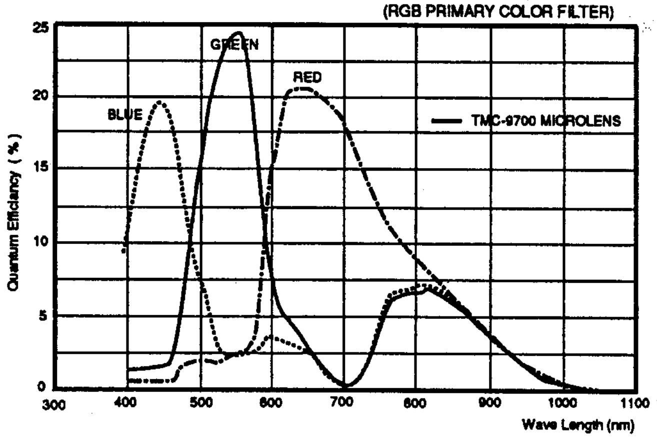
11.1 DIAGRAM OF 3 G, R/B STAGGERED PRIMARY COLOR FILTER

3 G, R/B STAGGERED FILTER

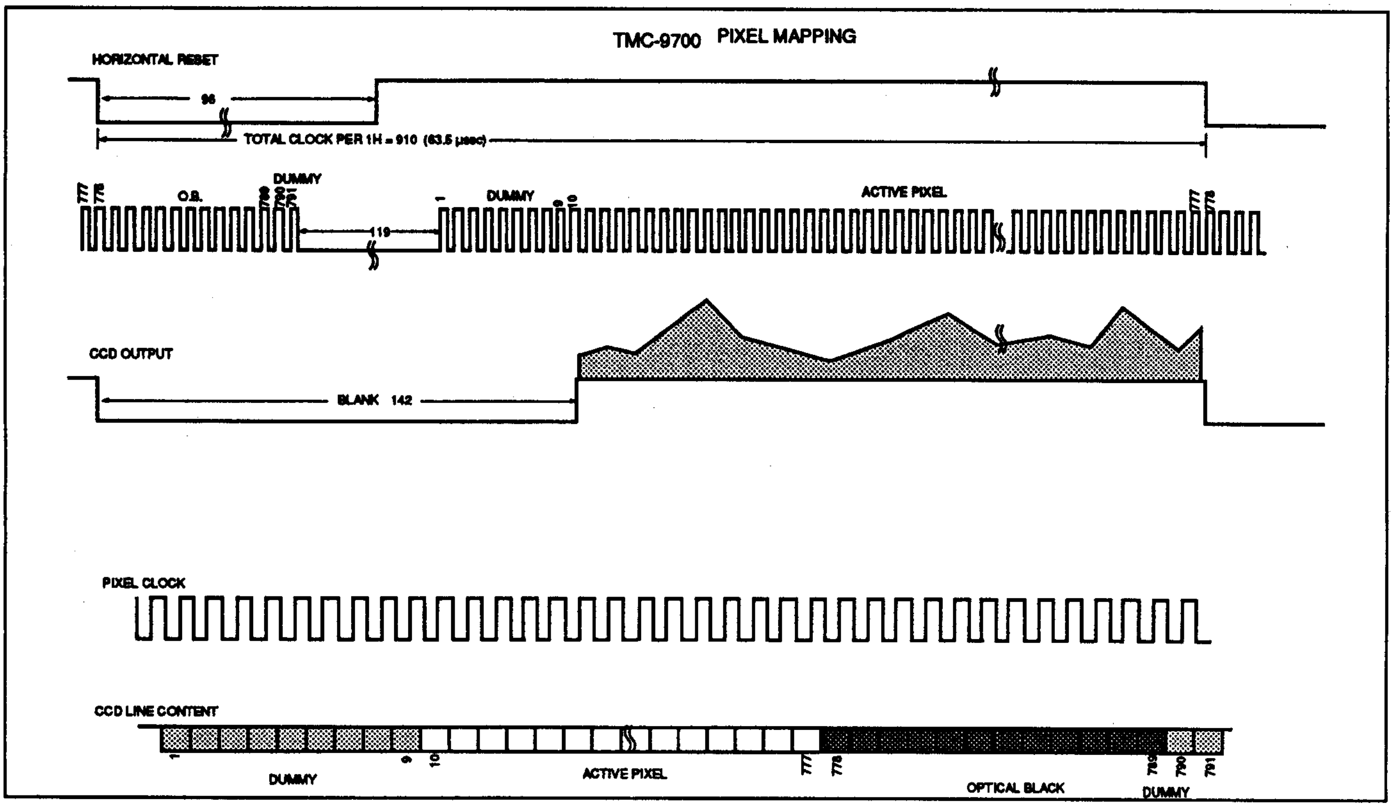


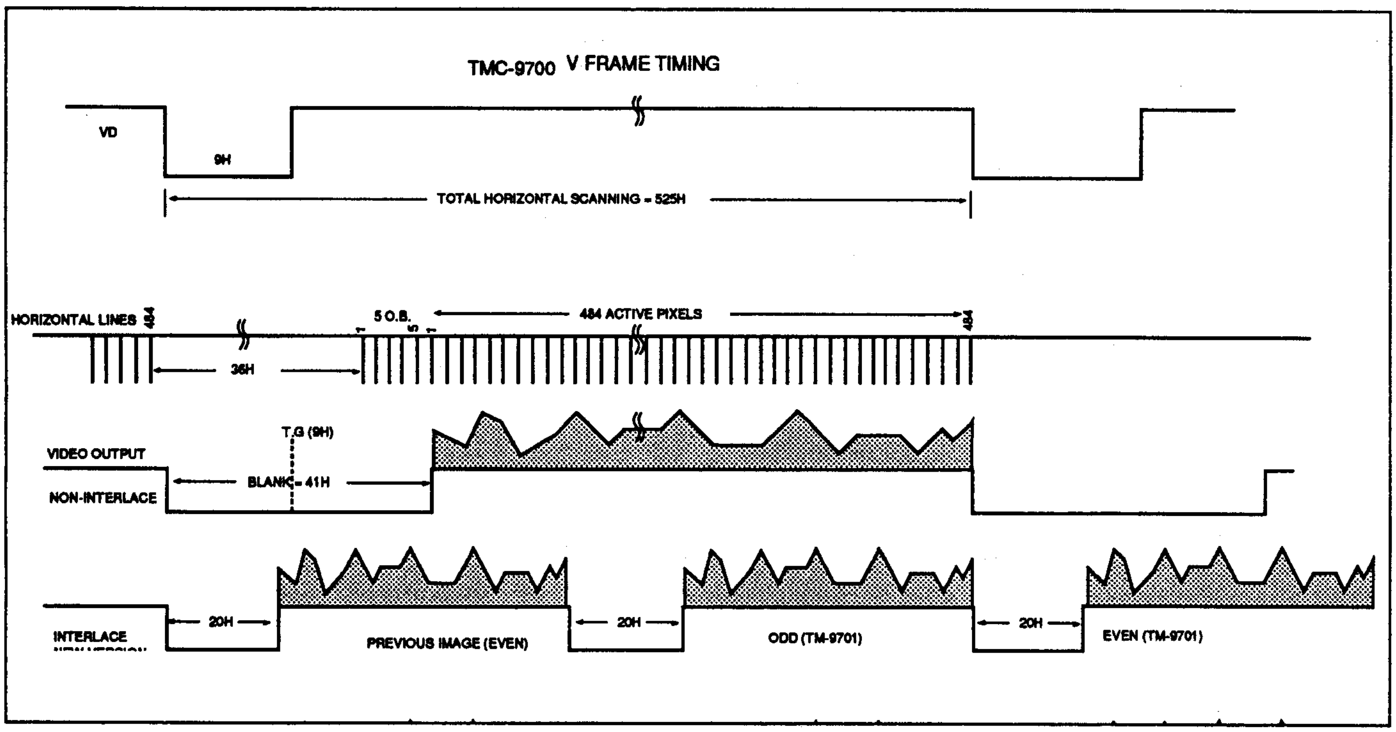
11.2 SPECTRAL RESPONSE OF RGB PRIMARY COLOR FILTER

COLOR SPECTRAL RESPONSE
(RGB PRIMARY COLOR FILTER)

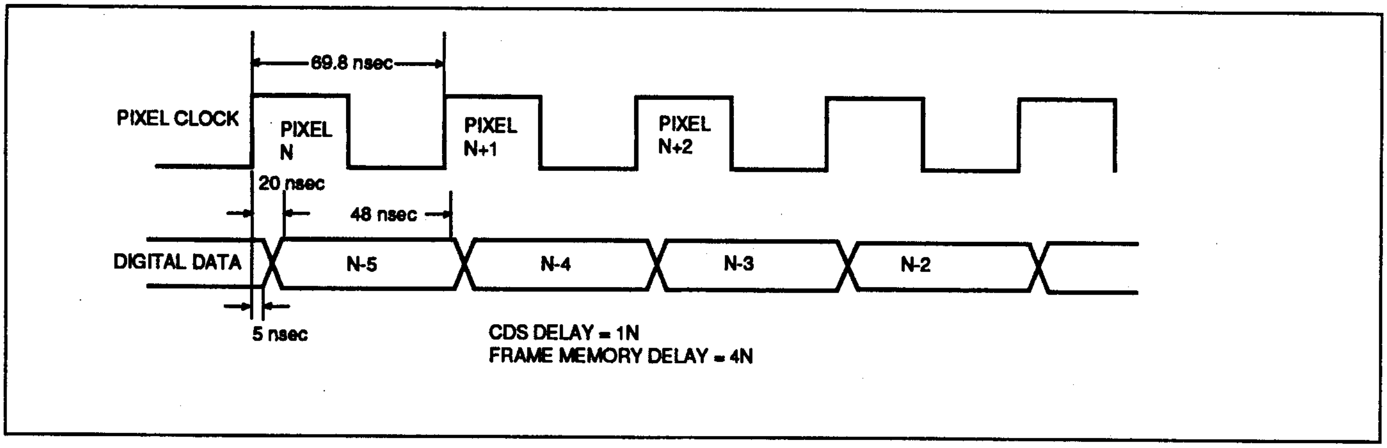


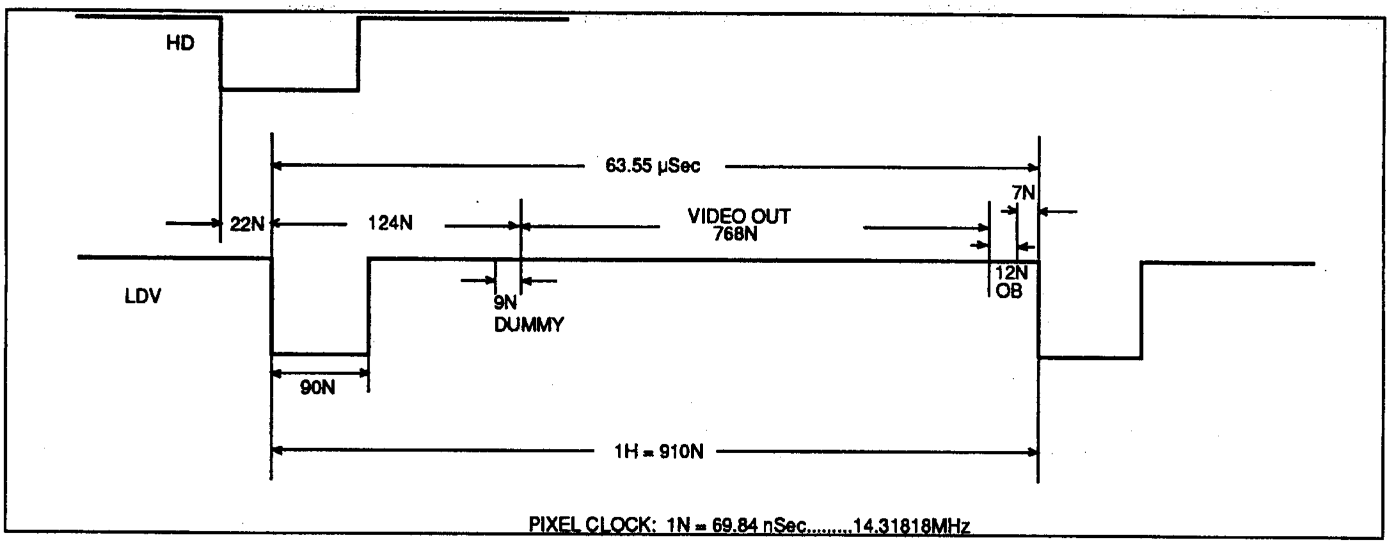
12 TIMING CHART FOR TMC-9700

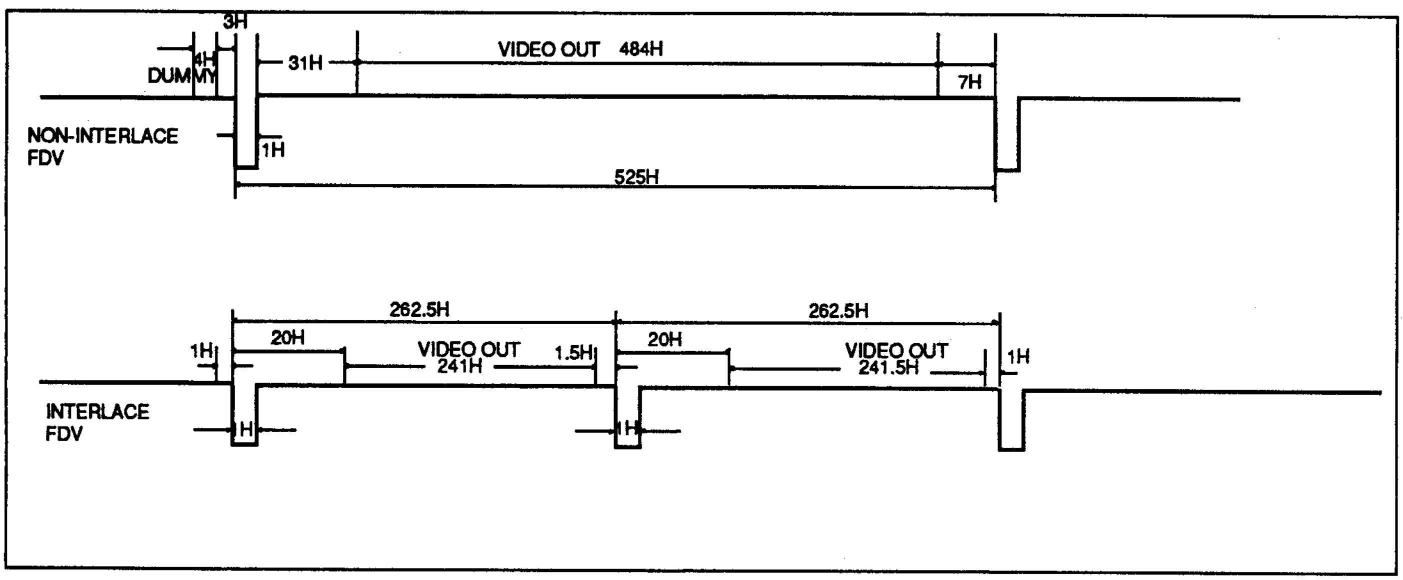




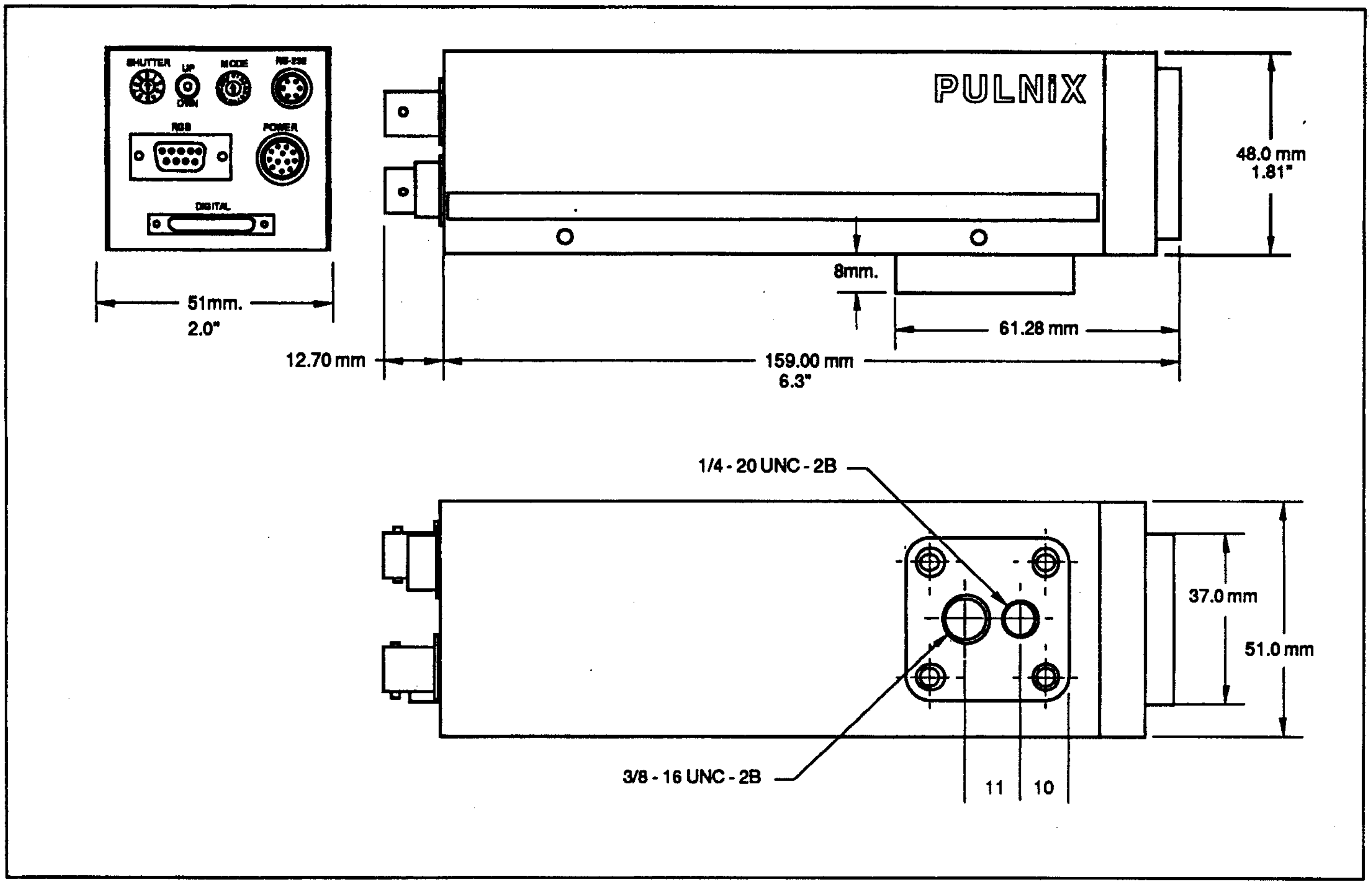
13 DIGITAL OUTPUT WAVE FORMS







14 MECHANICAL DRAWINGS
14.1 STANDARD CONFIGURATIONS



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