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PULNiX

TM-745E/TM-765E
HIGH RESOLUTION
CCD CAMERA

OPERATIONS &
MAINTENANCE MANUAL

69-0032 Rev. 1

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SECTION 1 FEATURES AND APPLICATIONS

HIGH RESOLUTION, INTERLINE TRANSFER CCD

The TM-745E/TM-765E is a state-of-the-art CCD camera which uses a 2/3 inch high resolution imager. This unit offers outstanding compactness, high performance, long life, high stability as well as a number of technical innovations such as variable electronic shutter and random CCD integration. Its diversified features allow for versatile applications such as machine vision and image processing, robotics, medical, and surveillance applications.

VARIABLE ELECTRONIC SHUTTER AND RANDOM CCD INTEGRATION

The TM-745E/TM-765E has a substrate drain-type shutter mechanism which provides a superb picture at various speeds without smearing. The camera has the capability to externally vary the electronic shutter rate via a manually controlled BCD switch from 1/60 to 1/10,000 sec. in discrete steps (1/31,000 sec. optional). Random field CCD integration is available . Full frame integration is possible through special modifications.

MINIATURIZED AND LIGHTWEIGHT

All PULNiX cameras are built with the same design principles, that is: solid state technology; miniaturization (including lenses, housings, and cables); specialization (such as remote imager and image intensified camera versions). The use of a CCD image sensor in the video camera module and the development of special mini C-mount lenses makes it possible to produce a very compact, lightweight, and robust series of cameras.

LONG LIFE: A THREE YEAR WARRANTY

The CCD solid state image sensor allows the camera to maintain a superior performance level indefinitely while requiring virtually no maintenance. PULNiX backs all of the TM series cameras with a three year warranty. **WARNING: Unscrewing the camera cover or opening the camera in any way will void this warranty.**

PRECISE IMAGE GEOMETRY

On the CCD image sensor, the photosensor elements form exact rows both horizontally and vertically so that a very precise image geometry may be obtained. Moreover, the TM-765E image sensor features uniform square pixels (11 x 11 microns) making it an obvious choice for use with computer image processing systems or for precise pattern measurements and gauging.

LOW LAG AND HIGH RESISTANCE TO IMAGE BURNING

Compared to the lag of conventional cameras which use a pickup tube, the lag of a CCD camera is considerably reduced so that a clear picture may be obtained when shooting a rapid moving object, or when shooting in a low illumination environment. Since the CCD is highly resistant to image burning, the camera may be exposed to bright objects for a long period of time. It must be noted that a "smear" phenomenon may occur when shooting a very bright object. An infrared cutoff filter is recommended to obtain a clear picture.

HIGH SENSITIVITY

The TM-745E/TM-765E is one of the most low light sensitive CCD cameras available today. This is especially important when using the faster shutter speeds. The CCD detects images into the near infrared. It requires only 0.5 lux of minimum illumination and 0.2 lux minimum illumination at maximum gain. In general, such a low light camera allows use of a higher lens F-value and provides greater depth of field and sharper images.

HIGH RESISTANCE TO MAGNETIC FIELD AND VIBRATION/MECHANICAL SHOCK

Due to its ruggedized design, the CCD imager can withstand strong vibration and shock, and little or no noise will appear in the picture. Since the TM-745E/TM-765E camera is not influenced by a magnetic field, it will produce stable images even when placed next to objects such as electric furnaces, welding machines, or NMR scanners.

QUICK START-UP AND LOW POWER CONSUMPTION

No more than a half second is needed for the TM-745E/TM-765E to warm up, and shooting may begin within a second after turning on the camera. The power consumption is only 4.0W. This makes the cameras excellent for use with battery operated systems.

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GENLOCK CIRCUIT
A genlock circuit is built into the TM-745E/TM-765E to accept external sync for industrial applications as well as for surveillance locking. This flexible genlock will take either interlace or non-interlace H and V sync.

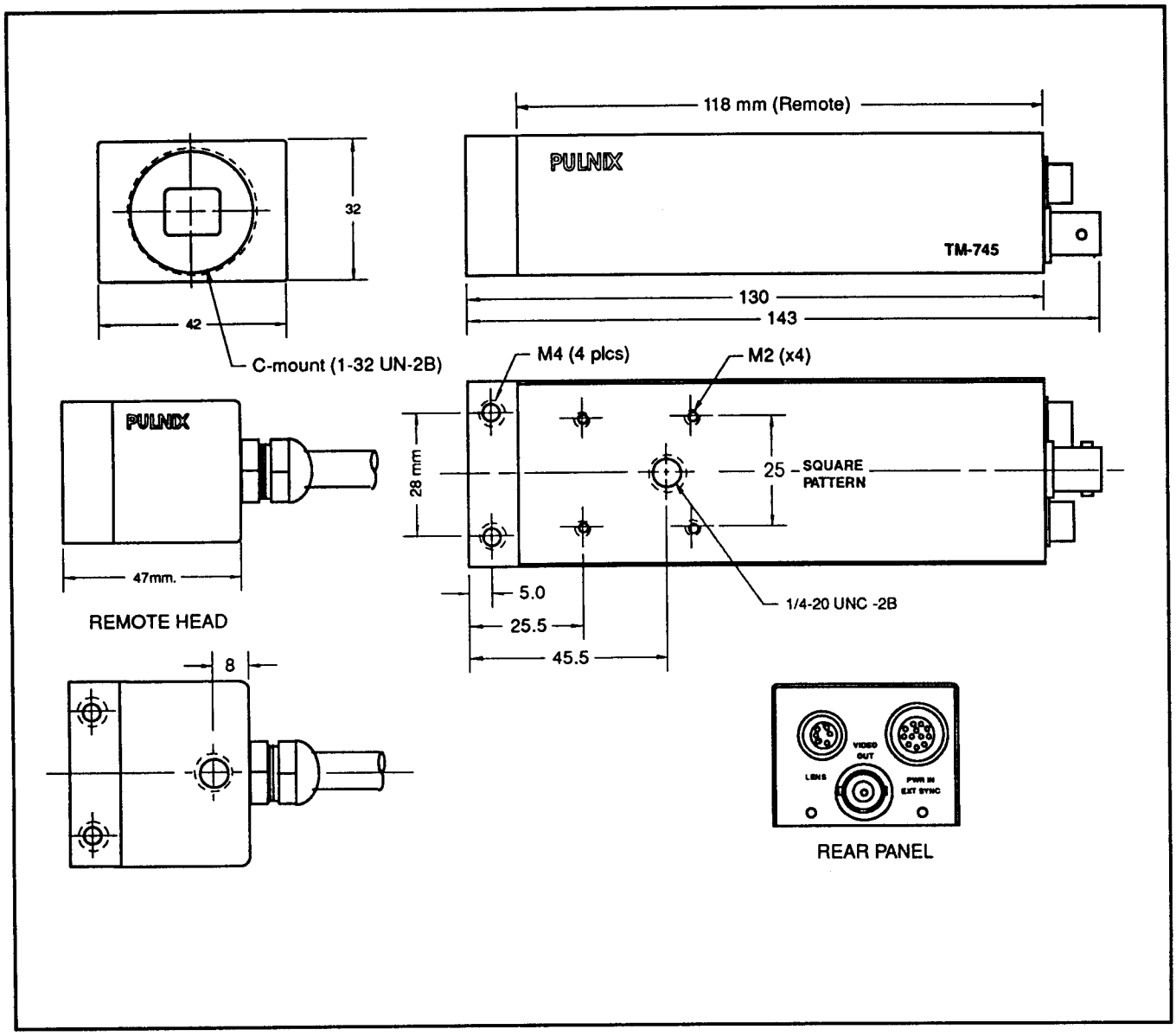
AGC SELECTION, MANUAL GAIN CONTROL AND GAMMA ADJUSTMENT
The AGC (automatic gain control) may be switched internally from automatic to fixed gain. Gamma may be set either to 1 or to maximum compensation 0.45. These adjustments are particularly important in vision system applications.

SECTION 2 SPECIFICATIONS

Imager:	2/3 inch interline transfer CCD
Pixels	768 (H) x 493 (V) - TM-745E
	756 (H) x 581 (V) - TM-765E
Cell size	11.0 (H) x 13.0 (V) microns - TM-745E
	11.0 (H) x 11.0 (V) microns - TM-765E
Sensing area	8.8 (H) x 6.6 (V) mm
Dynamic range	67dB
	Low noise, blooming suppression
Chip size	10.0 mm (H) x 9.3 mm (V)
Scanning:	525 lines, 2:1 interlace - TM-745E (EIA)
	625 lines, 2:1 interlace - TM-765E (CCIR)
Clock	28.6363 MHz - TM-745E
	28.375 MHz - TM-765E
Pixel clock	14.31818 MHz - TM-745E
	14.1875 MHz - TM-765E
Horizontal frequency	15.734 KHz - TM-745E
	15.625 KHz - TM-765E
Vertical frequency	59.94 Hz - TM-745E
	50.0 Hz - TM-765E
Sync:	Internal/external auto switch
External sync:	HD/VD, 4.0V p-p, 4.7KΩ impedance
	Frequency tolerance - within ±5%
	Interlace/non-interlace
	Jitter within 20 nsec. Locking time within 2 sec. (when power is on)
TV resolution:	570(H) x 485(V) lines - TM-745E
	560(H) x 575(V) lines - TM-765E
Video output:	1.0V p-p composite video, 75Ω
S/N ratio:	50 dB min.
Minimum illumination:	0.5 lux (F=1.4) without IR cut filter
AGC:	On (12dB standard, 17dB max) / Off
Gamma:	0.45 or 1
Lens mount:	C-mount
Power requirement:	DC 12V ± 10%, 250mA
Operating temperature:	-10 °C to +50 °C
Storage temperature:	-30 °C to +60 °C
Operating humidity:	Within 70%
Storage humidity:	Within 90%
Vibration:	7G (200Hz to 2000Hz)
Shock:	70G
Camera body:	51mm x 44mm x 159mm (L) 190 grams, 2.0" x 1.73" x 6.3"
Remote imager:	42mm x 32mm x 36.6mm (L) 20 grams, 1.65" x 1.26" x 1.44"
Remote imager cable:	48 inches standard; up to 84 inches optional

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SECTION 3 PHYSICAL DIMENSIONS



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SECTION 4 CAMERA SYSTEM ACCESSORIES

The TM-745E/TM-765E consists of the camera body and the lens mount. Additionally, PULNiX offers the following accessories:

4.1 **SHUTTER CONTROL UNIT** (SC-745) consists of a manually controlled 8-position BCD switch that determines the exposure time of the sensor. It connects to the TM-745E/TM-765E via a cable with a PC-6P male connector that plugs into the 6-pin female connector socket on the back of the camera. The SC-745 for shutter control is included with camera.

4.2 **POWER CABLES** - all power cables use a PC-12P female connector that fits into the 12-pin male connector on the back of the camera. Due to the connector's miniature size, PULNiX recommends purchasing the following pre-assembled cables: KC-10 10 feet, 4 conductor cable (12V, GND, Hd, Vd); 12POX variable length, 8 conductor cable (12V, GND, H_D, V_D, video, Async reset, integration control)
Note: Consult PULNiX for custom cable assemblies.

4.3 **LENSES** - PULNiX offers a wide variety of 2/3 inch format mini lenses. Auto-iris lenses must have a cable equipped with a PC-6P connector mating into the 6-pin female connector on the back of the camera.
Note: Normally, the TM-745E/TM-765E cannot do variable shuttering while using an auto-iris lens because these functions share one 6-pin socket. The user has to build his own interface in order to use both an auto-iris lens and a shutter control switch. This is done by separating the +12VDC, GND and video wires (for the auto-iris lens), and the D_0, D_1, and D_2 controls (for the BCD switch).

4.4 **POWER SUPPLIES** - PULNiX recommends the following supplies:

K25-12	110V AC/12V DC, 2.1A regulated supply
P-15-12	220V AC/12V DC, 2.1A regulated supply
K50-12	110V AC/12V DC, 4.2A regulated supply
PD-12P	110V AC/12V DC, 0.5A regulated supply

SECTION 5 SETUP AND OPERATION

The operation of the TM-745E/TM-765E requires a lens (mini or standard C-mount), a 12V DC regulated power supply, power and video cable assemblies and, if needed, a shutter control unit. Setup of the camera system is as follows:

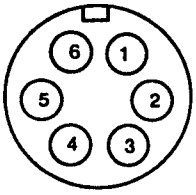
5.1 LENS MOUNT

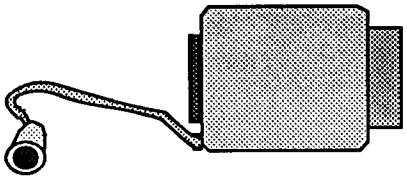
The TM-745E and TM-765E cameras have a permanent C-mount attached to the imager portion of the camera. Lenses are mounted by carefully threading the lens into the mount in a clockwise direction. Turn the lens until completely seated on the mount. Most all standard C-mount lenses should fit the TM-745E/TM-765E. However, some specialized lenses may have an extremely long flange back which exceeds the mounting depth of the camera. Do not force a lens which does not appear to fully seat. Lens extention tubes such as the CR-5, CR-10, and CR-20 are used by attaching first to the lens and then mounting the entire assembly to the camera. CS style lenses, though they share the common C-mount thread, are not compatible with the standard TM-745E/TM-765E mount due to a different rear focus specification for the CS format.

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5.2 AUTO-IRIS LENSES

Auto-iris lenses require a 6-pin male connector (PC-6P) mating into the female connector on the back of the camera. Connect +12V DC, GND and Video to each pin as indicated in the following.





6-PIN Connector

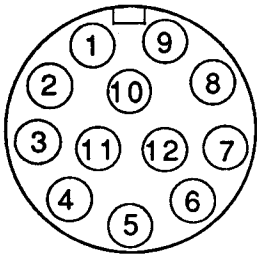
1. D2	4. +12V
2. GND	5. Do
3. Video	6. D1

5.3 SHUTTER CONTROL UNIT (SC-745)

The TM-745E/TM-765E uses a manually controlled 8-position BCD switch, SC-745, to set the shutter speed of operation. The switch is connected to the camera via a cable that has a PC-6P male connector attached to it which plugs into the above illustrated 6-pin camera socket.

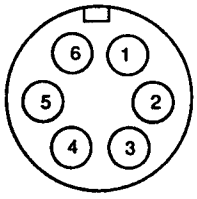
5.4 POWER CABLES AND POWER SUPPLIES

The TM-745E/TM-765E uses a PC-12P mating 12-pin power connector. If using any of the PULNiX connector and cable assemblies, please note that the yellow lead is +12V DC and gray is GND. Connect the yellow lead to the +12V of the power supply and attach the gray lead to the power supply's ground. Make sure all other leads are not touching as this will cause the camera to malfunction. When powering the camera, use only a regulated 12VDC power supply. The TM-745E/TM-765E has a narrow voltage intake range (11V to 14V max). If unregulated voltage or voltage lower than 11V is applied, noise will appear on the monitor.



12-PIN Connector

1. GND	7. V_D In
2. +12V DC	8. GND
3. GND	9. H_D In
4. Video Out	10. N/C
5. GND	11. Integration Control
6. Vinit	12. GND



6-PIN Connector

1. D2	4. +12V DC
2. GND	5. D0
3. Video	6. D1

NOTE: Do, D1, D2 are shutter control inputs.

5.5 VIDEO OUTPUT

The video output impedance of the camera is 75Ω and requires a coaxial cable with matching impedance. The end of the video cable or the monitor must be terminated at 75Ω as well. Standard video cable with proper video connectors may be obtained at most electronics hardware stores. Connect one end of the video cable into the standard video connector located on the back of the camera and insert the other end of the cable into the CCTV monitor. Alternatively, video output is also transmitted via pin 4 of the camera's 12 pin connector.

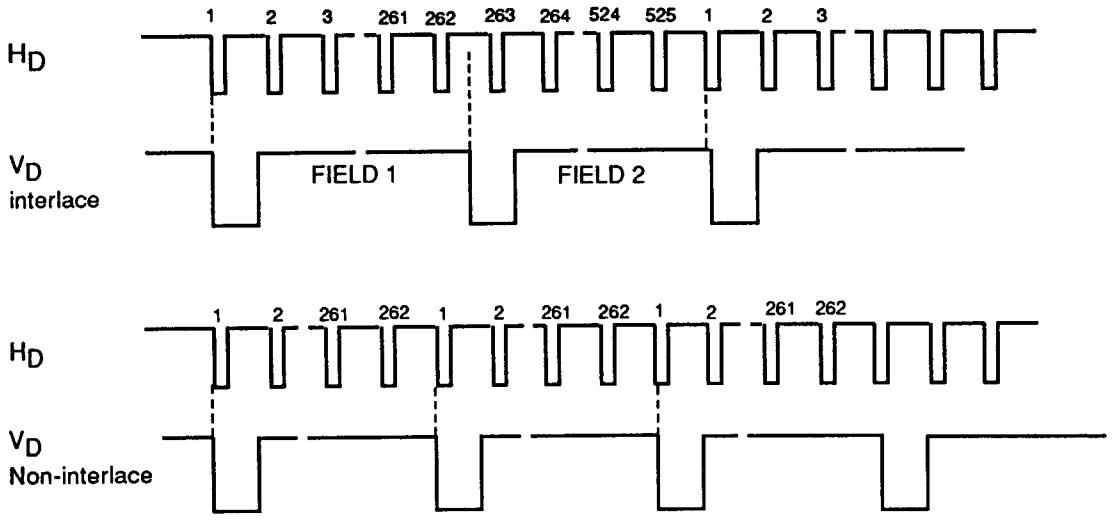
5.6 EXTERNAL SYNC

The TM-745E/TM-765E does not require external sync in order to run directly into a CCTV monitor. However, some applications (such as multiple camera switching and some vision systems) will require that the camera be externally synced. The unit has a built-in genlock circuit which will accept an external H_D and V_D sync signal; the built-in phase lock loop (PLL) adjusts its internal frequency to lock the camera to the external sync by allowing the internal crystal oscillator to automatically switch to a voltage controlled oscillator. Pins 7 and 9 of the TM-745E/TM-765E's 12-pin connector accept external V_D and H_D.

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5.7. INTERLACE/NON-INTERLACE

Interlace sync is a standard TV sync where the vertical sync alternates the odd and even fields of a frame of video. Non-interlace sync scans one field only. The pulse relationship is shown below.

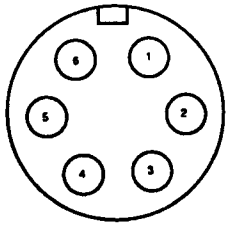


The internal genlock of the camera operates in the interlace mode. When external sync is applied, operation can be performed in either interlace or non-interlace mode by changing the input condition of the V_D signal as shown above.

SECTION 6 TM-745E/TM-765E SHUTTER CAMERA APPLICATION

6.1 BCD SHUTTER CONTROL

By selecting D0, D1, D2 level high or low, the following shutter speed is obtained, PULNiX provides a shutter control (SC-745), but it is easily controlled from the computer, remote control unit, or fixed at a certain speed.



6-PIN Connector

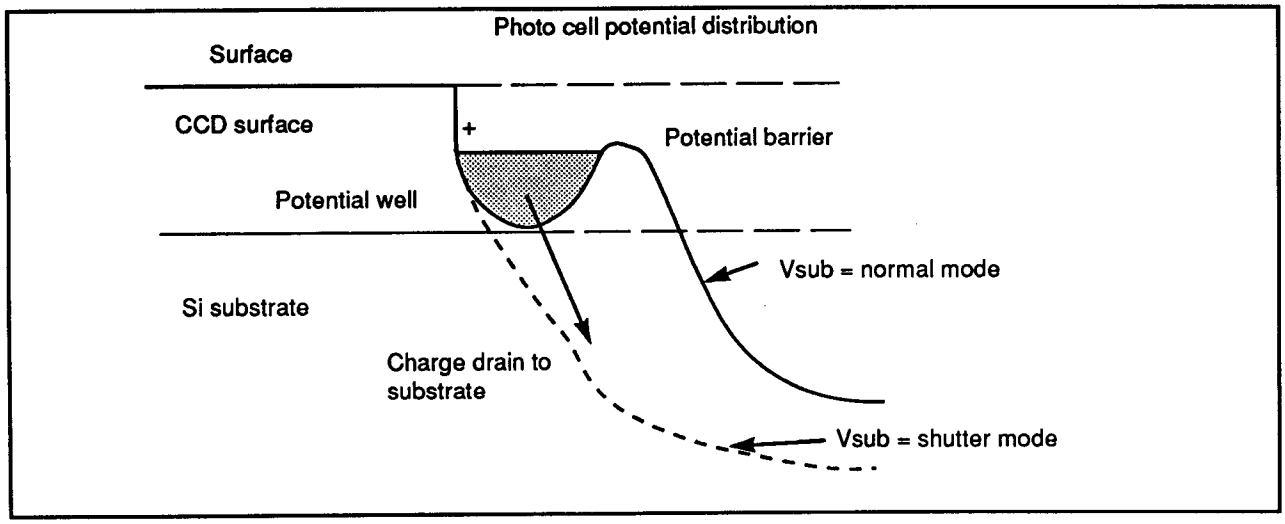
1. D2
2. GND
3. Video
4. +12V
5. D0
6. D1

Shutter control SC-745

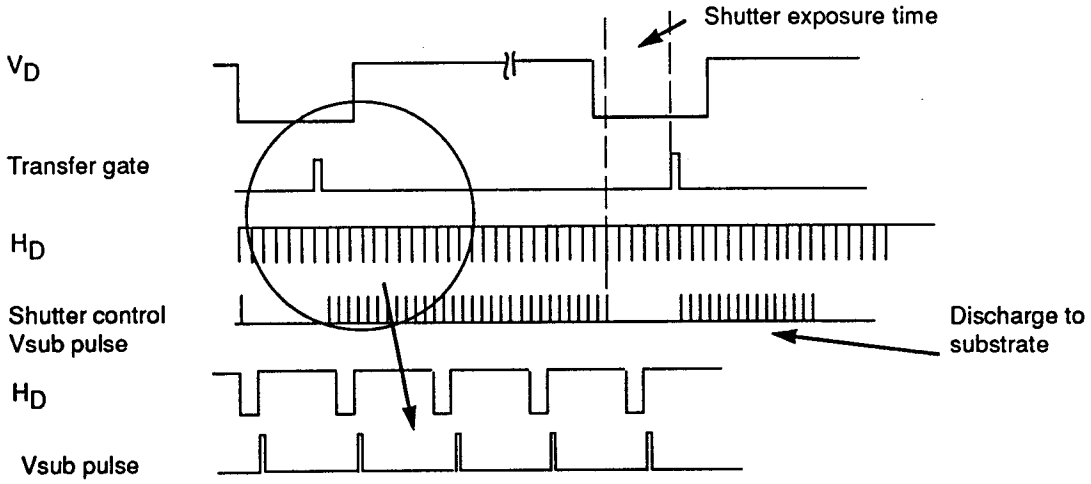
Controller Setting	0	1	2	3	4	5	6	7
sec	1/60	1/125	1/250	1/500	1/1000	1/2000	1/4000	1/10,000
D0	L	H	L	H	L	H	L	H
D1	L	L	H	H	L	L	H	H
D2	L	L	L	L	H	H	H	H

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6.2 SUBSTRATE DRAIN SHUTTER MECHANISM



Normal operation requires the CCD chip to construct an individual potential well at each image cell. These potential wells are separated from each other by a barrier. The barrier is sequentially removed to transfer the charge from one CCD to another by the pixel clock. This is the basic principle of CCD operation for interline 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 done with a horizontal charge shift to the drain area by interline transferring or reverse transferring of the frame transfer chip.



The discharge of TM-745E/TM-765E is done in the horizontal blanking interval.

Note: Vertical resolution of shutter mode is one field (244). Full frame shutter is not available. If the object is still, the interlace signal (2 fields) can generate full vertical resolution.

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6.3 HIGH SPEED SHUTTER OPTION

With optional modification (option #29-4), The TM-745E/TM-765E is capable of increasing the shutter speed up to 1/31,500 sec.
The BCD control for high speed option is:

Digit SW	Do	D1	D2	Standard	High Speed (option #29-4)
0	L	L	L	1/60	1/60
1	H	L	L	1/125	1/126
2	L	H	L	1/250	1/254
3	H	H	L	1/500	1/508
4	L	L	H	1/1000	1/1050
5	H	L	H	1/2000	1/2250
6	L	H	H	1/4000	1/5250
7	H	H	H	1/10,000	1/31,500

6.4 INTEGRATION

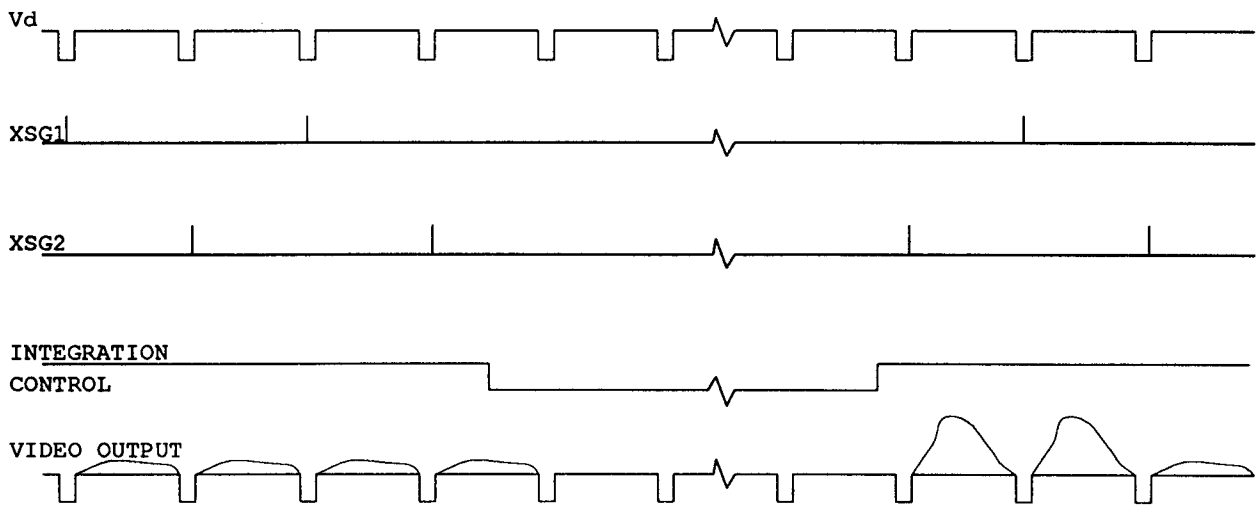
The TM-745E/TM-765E can operate with long exposures (Integration mode). Due to the interline transfer, full frame resolution is obtained. (Note: Full frame is not available in the shutter mode).

1. Select frame mode on driver PCB (Factory standard). If the setting is in the field mode in order to enhance shutter sensitivity, move solder jumper to frame side.

2. Apply the integration control to low (GND) to pin #11 of 12-pin connector. This allows the TM-745E/TM-765E to operate with integration.

3. Apply ext. sync (H_D, V_D); H_D - continuous, V_D - continuous or integration control interval pulse.

6.5 INTEGRATION CONTROL PULSE



NOTE: 1. XSG1 and XSG2 are transfer gate pulses. They are approximately at 7.5H (11.5H for TM-765) after Vd falling edge.
2. No transfer gate pulse when INTEGRATION CONTROL is LOW.
3. Two fields of integrated image is available after INTEGRATION CONTROL changed to HIGH.

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SECTION 7 CAMERA VERSIONS AND OPTIONS

1. Automatic gain control (AGC) disabled - gain set to fixed value.

2. Blemish free imager - no bad pixels or compensating PROMS.

3. Internal infrared (IR) filter. All remote imager versions are already equipped with it.

4. Gamma adjusted to 0.45 - standard gamma is set to 1.

10. Remote imager cable enters at the rear.

11. Remote imager cable enters at the right.

12. Remote imager cable enters at the left.

13. Remote imager enters at the top.

14. Remote imager enters at the bottom.

15. Detachable remote imager at the camera body.

23. Pixel clock out.

25. Pinout compatible with Sony XC-38/39.

29. Set shutter at 1/30,000 sec.

SECTION 8 CCD CHARACTERISTICS AND OPERATION

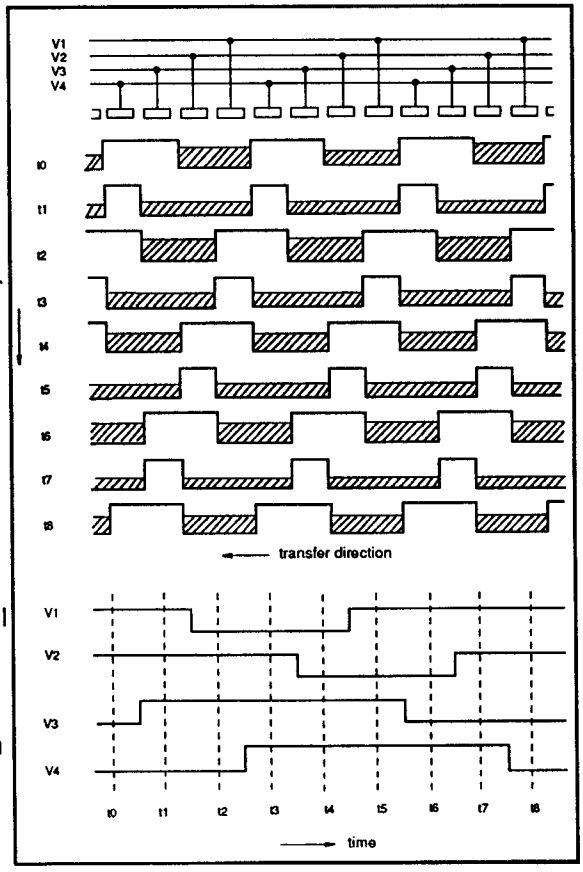
8.1 **THEORY OF OPERATION** (Operation principle of the CCD)

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

1. Photoelectric conversion (photosensor)
Incident light generates charges on the MOS capacitors, with the quantity of charge being proportional to the brightness.

2. Accumulation of charges
When a voltage is applied to the electrodes of the MOS capacitors, an electric potential well is formed in the silicon layer. The charge is accumulated in this well.

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



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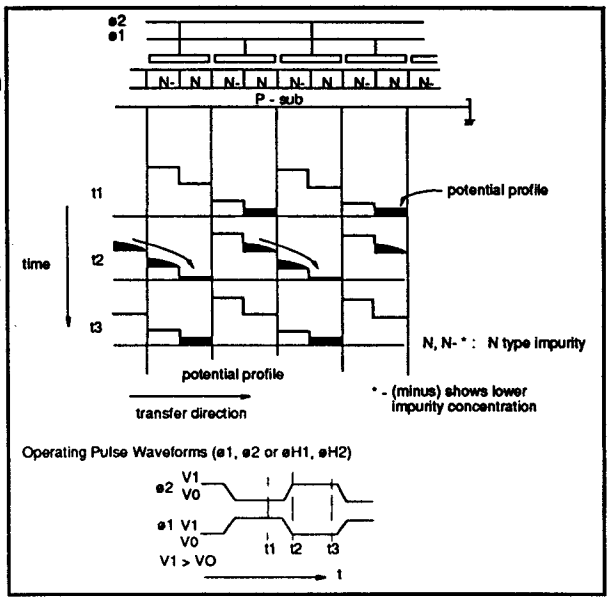
8.2 MECHANISM OF CCD CHARGE TRANSFER

1. Vertical transfer

The vertical shift register transfers charges using a four-phase drive mode. Figure 1 shows an example of the changes which can occur in potential wells in successive time intervals. At tO, the electrode voltages are (V1 = V2)>(V3 = V4), so the potential wells are deeper toward the electrode at the higher voltages V1 and V2. Charges accumulate in these deep wells. At t1, the electrode voltages are (V1 = V2 = V3)>(V4), so the charges accumulate in the wells toward the electrode at V1, V2 and V3. At t2, the electrode voltages are (V2 = V3)>(V4 = V1), so the charges accumulate in the wells toward the electrode at V2 and V3. Electrode voltage states at t3 and after are shown below.

t3(V2 = V3 = V4)>(V1)
t4(V3 = V4)>(V1 = V2)
t5(V4>(V1 = V2 = V3)
t6(V4 = V1)>(V2 = V3)
t7(V4 = V1 = V2)>(V3)
t8(V1 = V2)>(V3 = V4) (Initial state)

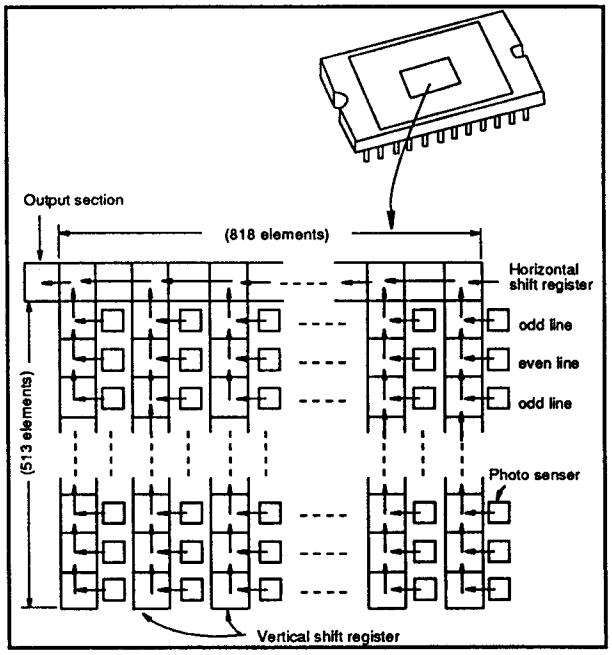
These operations are repeated to execute the vertical transfer.



The interline-transfer mechanism of the CCD

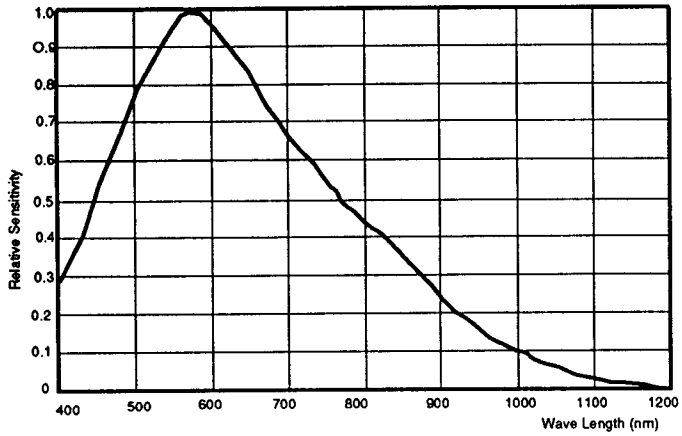
2. Horizontal transfer

The horizontal shift register transfers charges using a two-phase drive mode. Figure 2 shows an example of the changes which can occur in the potential wells in successive time intervals. At t1, the electrode voltages are H1>H2, so the potential wells are deeper toward the electrode of the higher voltage H1. The charges accumulate in these wells. At t2, the electrode voltages H1 and H2 are inverted, the wells toward the electrode at voltage H2 becomes deeper while the wells toward the electrode at voltage H1 become shallower. So the wells at H2 are deeper than those at H1, the charge flows into the deeper wells toward the electrode at H2. At t3, the electrode voltage has not changed since t2, so the charge flows into the wells at H2 and one transfer of charge is completed. These operations are repeated to execute the horizontal transfer.



Two phase CCD charge transfer

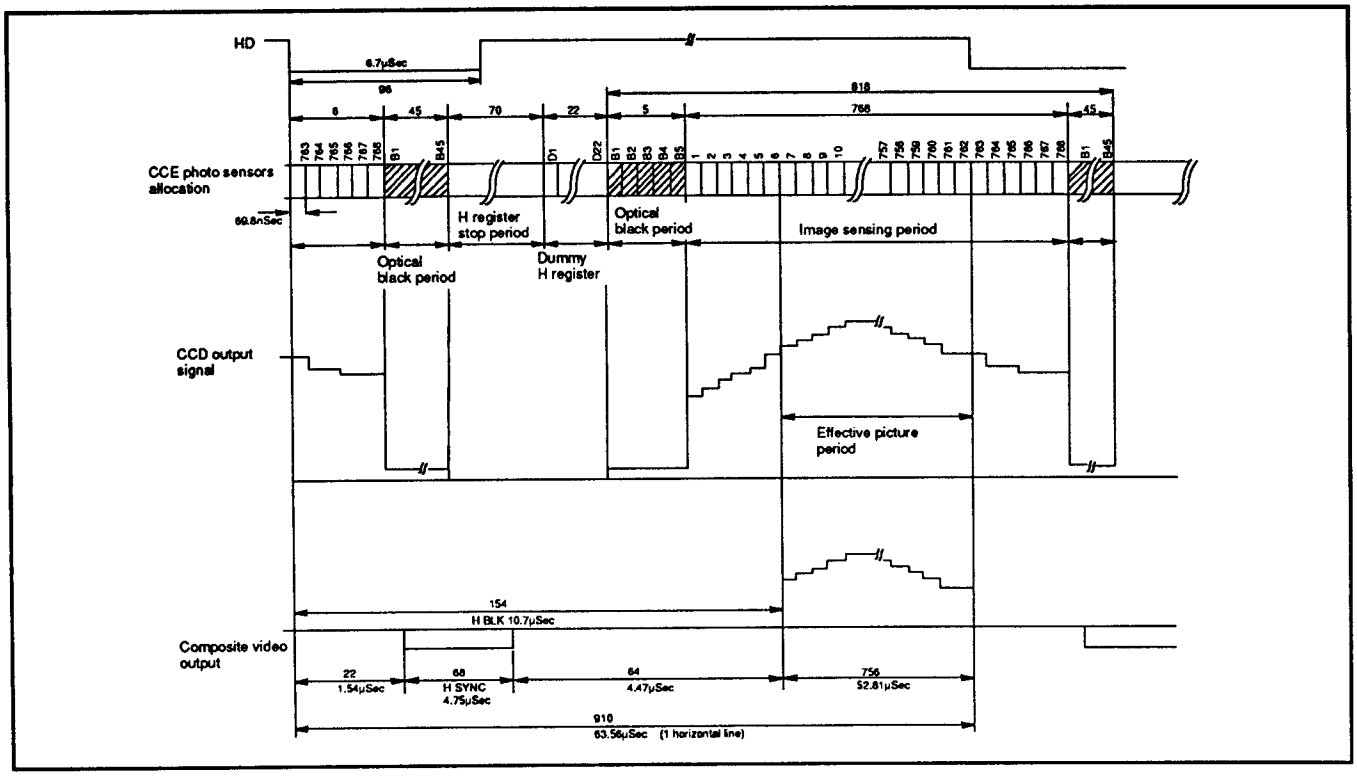
8.3 SPECTRAL RESPONSE

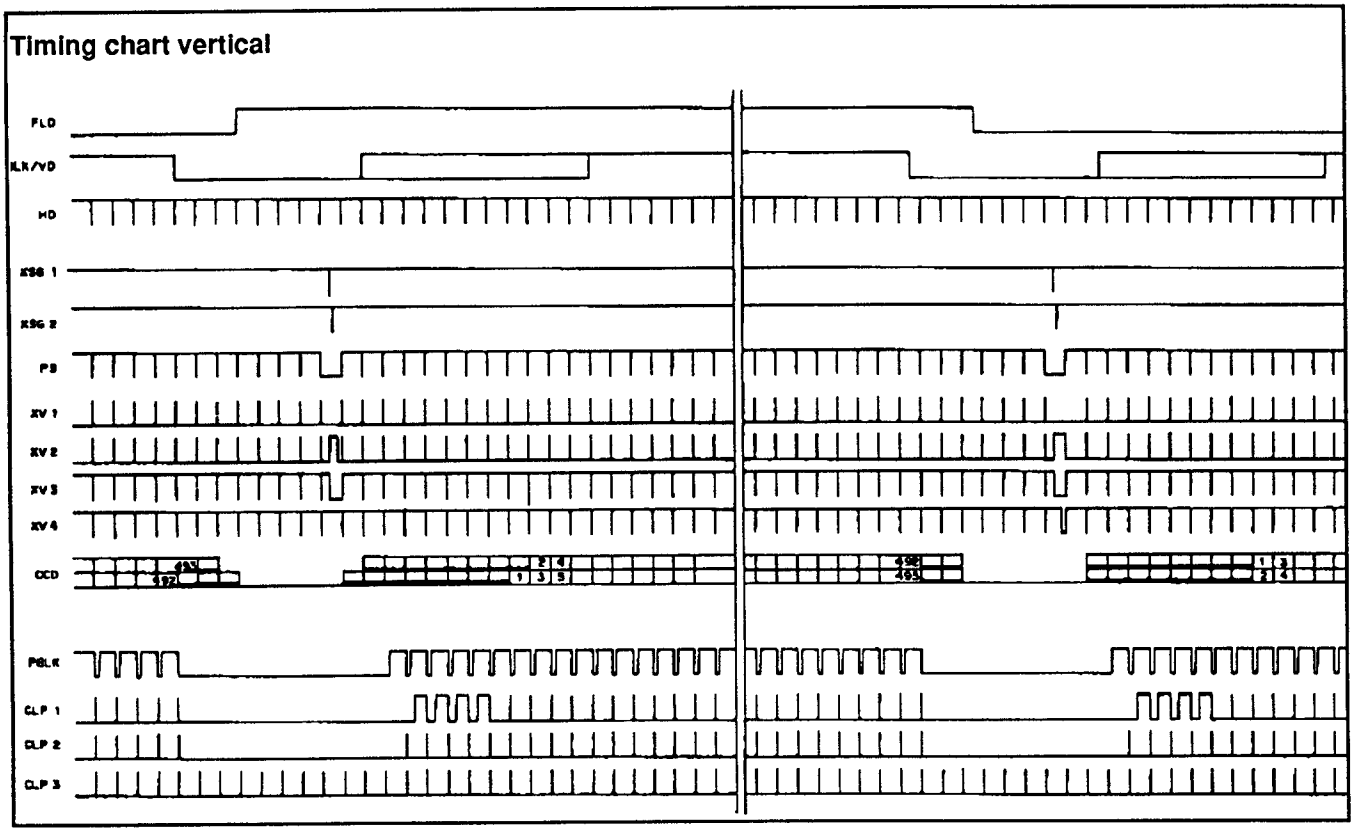


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SECTION 9 TIMING CHARTS and SPECIAL FUNCTIONS

9.1 OUTPUT SIGNAL TIMING CHARTS

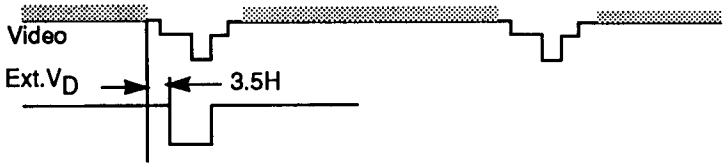


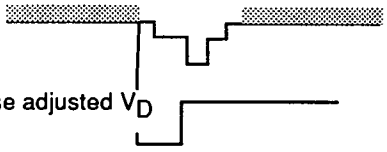


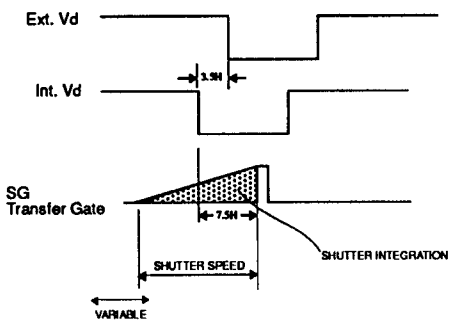
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9.2 SPECIAL FUNCTIONS:

9.2.1 SHUTTER The TM-745E/765E has a built in shutter control up to 1/10,000 sec. As an option, 1/31,500 sec. shutter speed is available. When this option is selected, V_D phase adjustment option is not available. VD phase adjustment is used to align video vertical timing to external sync leading edge. Standard without adjustment is 3.5H (fixed).







The shutter timing is synchronized with the CCD transfer gate timing of each field. Because of the shutter principle, only one field image per shutter is output. If one frame of shutter image is captured, two separate images will be displayed due to object motion.

9.2.2 INTEGRATION Integration is a longer exposure than the standard 1/30 sec. of frame speed. The TM-745E/765E provides a full frame of integration image. Pin 11 of the 12-pin connector is used to control integration. The standard model is normally pulled up (5V), and when Pin 11 is Low (GND), the TM-745E/765E maintains the integration until Pin 11 goes to high.

The integration image is quite different from TM-840N(frame transfer CCD). TM-745E/765E signal processing keeps optical black level as reference black video to clamp the video level, and thermal noise during integration is cancelled off. Non-optical black clamping is also available as an option. Please consult PULNiX for special integration applications.

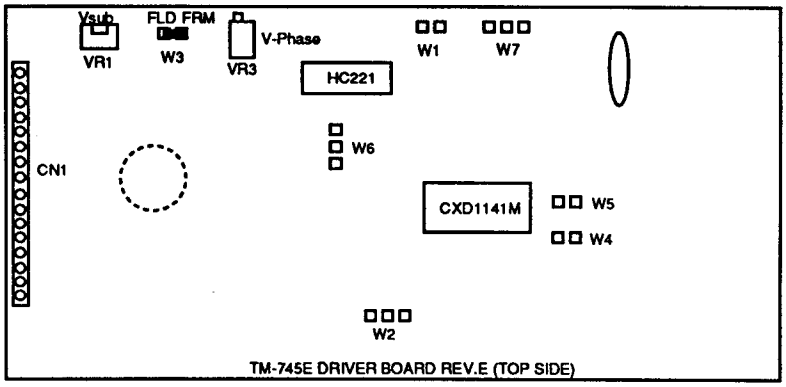
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SECTION 10 FACTORY SETTING AND BOARD LAYOUTS

10.1 DRIVER BOARD (TOP SIDE)

Jumper Setting:

W1	OPEN	
W2	OPEN	
W3	FLD/FRM	FRM(Short)
W4	OPEN	
W7	OPEN	



Voltage Setting:

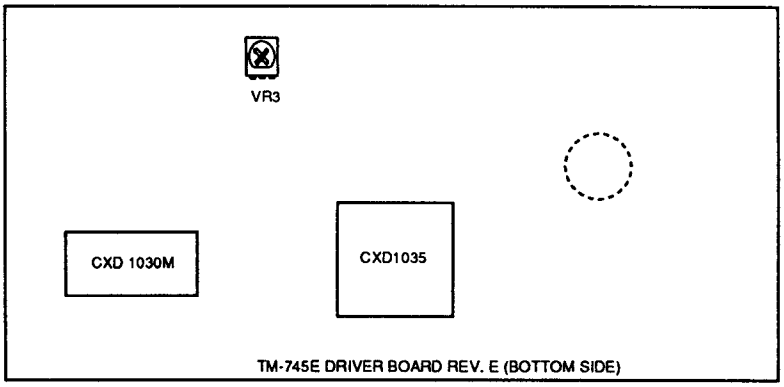
VR1	Vsub	Optimize it by checking the picture, make sure there is no grainy picture.
VR3	VD Phase	Apply ext. VD to the camera, and probe int. HD. Adjust VR2 so that both ext. vD and Int. VD will be lined up.

10.2 DRIVER BOARD(BOTTOM SIDE)

Voltage Setting:

VR2 PLL

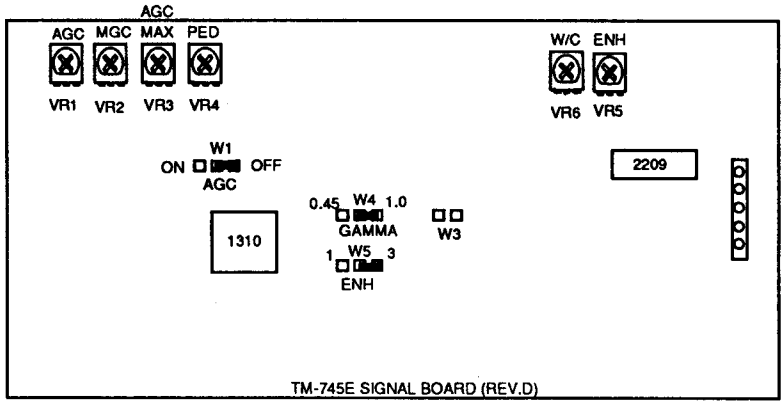
Apply ext. HD to the camera, and probe int. HD. Adjust VR1 so that both ext. HD and int. HD phase will be lined up. The delay should be less than 20 nsec.



10.3 SIGNAL BOARD

Jumper Setting:

W1 AGC ON/OFF AGC OFF(RIGHT)
W4 GAMMA 1/0.45 1.0 (RIGHT)
W5 ENH ON(3)/OFF(1) ON (RIGHT)



Voltage Setting:

VR1	AGC	1.9±0.1V
VR2	MGC	3.2±0.1V
VR3	AGC MAX	2.0±0.1V
VR4	PED	50±0.1mV
VR5	ENH	0V
VR6	W/C	0V

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Revised Printing: December, 1995

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