PULNiX

# TM-4000CL

AccuPiXEL Dual-tap Series


## General Description

The TM-4000CL is a miniature, very high-resolution (4.2 Mpixels) monochrome progressive scan CCD camera with dual tap output. The imager resolution is 2048 x 2048 pixels and the frame rate is 15 frames per second. The interline transfer CCD permits full vertical and horizontal resolution of high-speed shuttered images. The electronic shutter has speeds up to 1/16,000 sec. and can be reset asynchronously by external pulse control.

The TM-4000CL has a patent-pending, PULNiX exclusive, built-in look-up table (LUT) and automatic dual channel compensation. This full dynamic range control function can be set at externally selectable knee slopes to optimize the CCD's full dynamic range in the normal output signal range. It also provides fast 10-bit (10-bit x 2) to 8-bit (8-bit x 2) pre-processing for effective image feature enhancement. The camera has both analog (multiplexed to single channel output) and digital (Camera Link) output for interfacing with frame grabbers.

All camera control functions are externally controlled via a user-friendly Camera Link serial graphical interface provided by PULNiX.

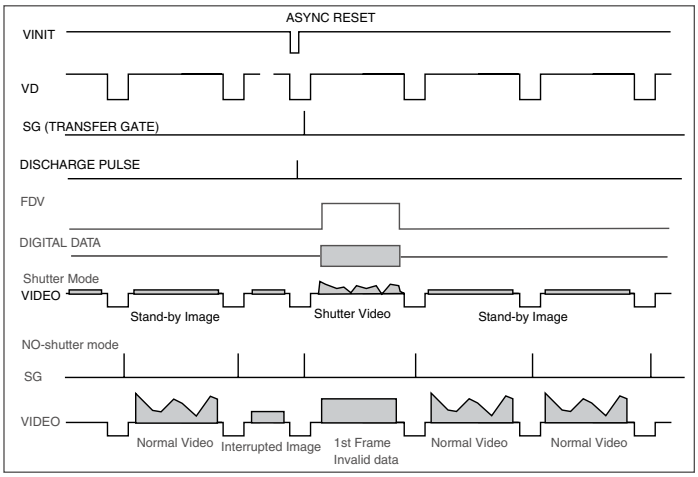
Applications for the TM-4000CL include machine vision, medical imaging, intelligent transportation systems, high-definition graphics, gauging, character recognition, documents archiving, and surveillance.

## Asynchronous Reset

The TM-4000CL's asynchronous reset is flexible and accepts external horizontal drive (HD) for phase locking. When the VINIT pulse is applied, it resets the camera's scanning and purging of the CCD. There are two modes to control the asynchronous reset and shutter speed:

1 External VINIT with pulse width. The duration between pulse edges controls the shutter speed externally.

2 Internal shutter speed control. The speed control varies from 1/125 to 1/16,000 sec. The video signal and FDV starts with internal V reset timing related to shutter speed.




## Product Summary

- **High-resolution 1.2" progressive scan 2048(H) x 2048(V) interline transfer CCD imager**
- **Miniature 50.8x50.8x81.5 mm housing with high-rel connector**
- **Digital Camera Link dual tap output and analog output (ch.A only)**
- **15 frames per second**
- **Maximum dynamic range control with PULNiX-exclusive, patent-pending built-in look-up table (Gamma, knee, user parameters)**
- **Full frame integration, partial scan (1000, 500, 250 lines)**
- **Full-frame shutter to 1/16,000 sec.**
- **Asynchronous reset, no-delay shutter and read-out-inhibit control for multiple camera applications**
- **Camera Link external control**
- **Automatic dual-channel compensation**
- **Built-in pattern generator and scan conversion**
- **Color version (RGB Bayer CFA) is available (TMC-4000)**

## Electronic Shutter

The TM-4000CL has a substrate drain-type shutter mechanism which provides a superb picture at various speeds without smearing. A built-in manual shutter speed control selects the electronic shutter rate of 1/60 (non-async mode only), 1/125, 1/250, 1/500, 1/1,000, 1/2,000, 1/4,000, 1/8,000, or 1/16,000 second.

The CCD discharges when discharge pulse is applied via internal shutter control. With a negative pulse to VINIT, the camera resets and purges the CCD charge momentarily. Then it starts integrating for the period of preset shutter control time by either an external pulse width or internal shutter control.

Progressive scanning permits a full 2048 lines of vertical resolution, as compared to a conventional CCD camera which captures only half the vertical lines per shutter.

## Integration

The CCD imager of the TM-4000CL can be exposed for longer than the normal scan timing of 1/15 sec. This integration feature provides extra sensitivity for dark-environment applications. The progressive-scan imager permits a full frame of resolution in non-interlace format. Integration is achieved by applying INTEG signal to the ccl2 control of Camera Link, or by feeding VINIT pulse width control up to 1 sec of the pulse width in async pulse width control mode.

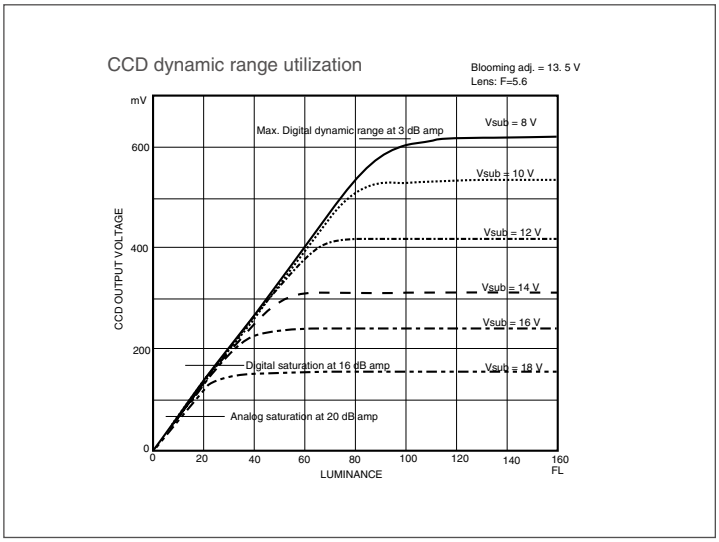
## Dynamic Range Control

Typical interline transfer CCDs have fixed noise levels based on dark current (thermal or KT noise), pattern noise, and operating clock speed. Typically for a 2k x 2k CCD operating at 40MHz pixel clock, the noise level is around 50 electrons. The maximum capacity of the CCD charges is limited by the well capacity at saturation. The range is limited by the structure and the pixel size.

The TM-4000CL uses a 1.2" CCD with 7.4 µm x 7.4 µm pixel and two-phase vertical shift register structure. The well capacity is 42,000 electrons. The theoretical dynamic range is 42,000:50 = 840:1 (58 dB).

A typical CCD camera does not use the full dynamic range due to the nominal gain and the output specification such as RS-170. The typical CCD camera has its gain set at 16 to 22 dB and the RS-170 video level is 714 mV. Using 20 dB gain for the calculation, CCD output is limited to 714/10 = 71.4 mV. Since the CCD's saturation voltage is 400 mV to 500 mV, it uses less than 1/5 of the full dynamic range.

Machine vision and outdoor applications cannot afford to miss image information behind the saturation, which is why the dynamic range adaptation is critical.



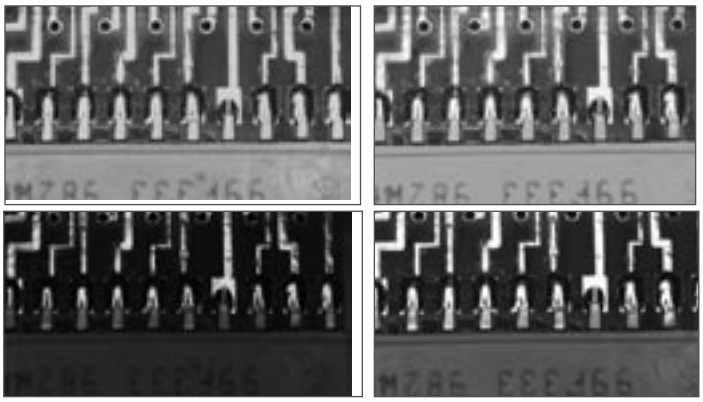

## Programmable LUT and Knee Control

**(patent pending)**

The TM-4000CL has a built-in LUT (look-up table) for dynamic range control.

At a specific gain setting, the offset (minimum level... dark point) and A/D reference top voltage (maximum level... saturation point) are set to 10-bit A/D input so that the full dynamic range of the CCD is utilized at 10-bit references as the input and the LUT output is converted into 8-bit to adjust the gamma correction.

The look-up table has two knee points (variable gamma selection) that allow the 10 bits to be segmented into three regions. The look-up table selection can be made either by variable knee curve or by direct input of the knee coordinates.



Linear image: When the PCB surface is visible, the metal trace is saturated. If the metal surface appears, then the plastic surface is too dark.

Two different knee-controlled images: Both show the full dynamic range with different effects.

## Scan Mode

### Full Progressive Scan

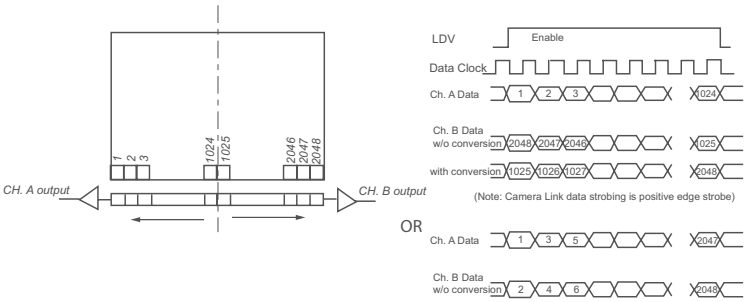
Normal scanning mode for the TM-4000CL is 2048 x 2048 pixels. The standard speed with dual-channel output is 15 frames/sec at the pixel clock of 40.0 MHz*. Unlike an interlace scan camera, the TM-4000CL reads every line from top to bottom, resulting in all lines being obtained per captured image frame with electronic shutter.

### Partial Scan

Partial scan has 3 scan options from which you can select: 1000, 500, or 250 lines. It outputs image center of 1000 lines, 500 lines and 250 lines. At 1000 lines the frame rate is 28 fps. At 500 lines, it is 50 fps, and at 250 lines it is 80 fps.

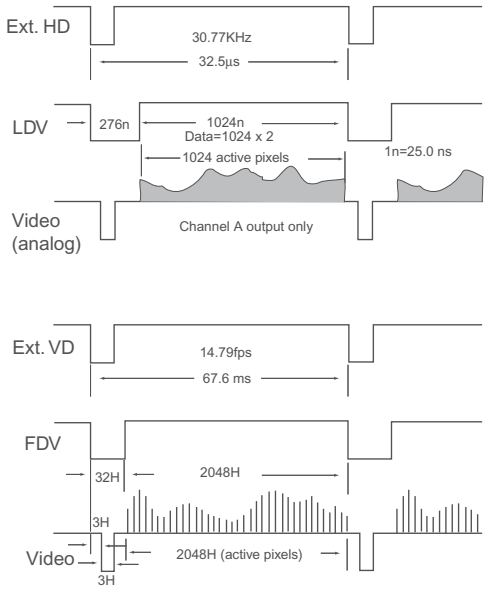
### Dual Tap Output

The TM-4000 has built-in line buffers to select channel B output direction. CCD output is split into two channels. The left half outputs data from 1 to 1024 (ch.A) and the right half outputs from 2048 to 1025 (ch.B). The internal line buffer corrects the right half (ch.B) output to start from 1025 to 2048 so that frame grabber does not have to convert the pixel orders. The output order is selectable.



## External Sync

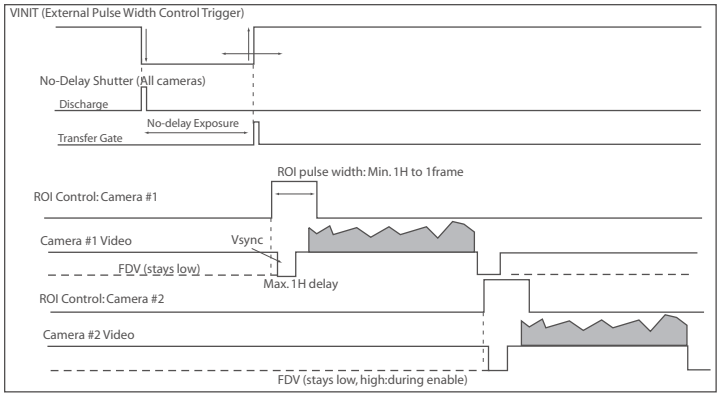
The TM-4000CL accepts an external sync. of standard HD and VD at TTL level for general locking to a system sync. and clock. The external sync. is available for 15-frame mode. The frequency requirement is as follows:
fHD = 30.77 KHz ±0.2% (split image scanning)
fVD = 14.79 Hz ± 2%
(Internal Master clock = 80.0 MHz,
Pixel clock = 40.0 MHz)
Please contact PULNiX for TM-4000CL timing charts.




## No-Delay Shutter and Read-Out-Inhibit

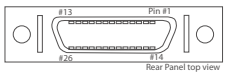
For multiple-camera applications such as 2D or 3D measurement and multi-angle inspection, simultaneous image capturing at an exact shutter timing for all cameras is a critical requirement. The TM-4000CL's **async pulse width control mode** provides no-delay shutter as standard. Regardless of internal pulse timing, it discharges at VINIT's leading edge and transfers charges at the trailing edge of the pulse. Even though each camera runs with slightly different H and data clock timing, image capturing is exactly simultaneous.

The TM-4000CL also has read-out-inhibit control (ROI) to control the vertical clock start **(Async Shutter #9).** When ROI is low, V-clock is stopped and the transferred charges remain in the vertical shift registers, which works like CCD memory. When ROI is high, it clocks out the CCD data. This helps a single frame grabber process multiple images in pipeline processing (sequential process).




## Connector and Pin Configurations

### Digital Output Connector




Camera Link Connector
MDR-26

DR 26-pin connector 10226-6212VC

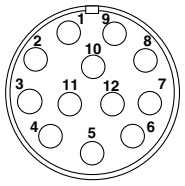
| Pin# | Description | I/O | Pin# | Description | I/O |
|---|---|---|---|---|---|
| 1 | GND | | 14 | GND | (Shield) |
| 2 | Tx OUT 0- | Out | 15 | Tx OUT 0+ | Out |
| 3 | Tx OUT 1- | Out | 16 | Tx OUT 1+ | Out |
| 4 | Tx OUT 2- | Out | 17 | Tx OUT 2+ | Out |
| 5 | Tx CLK OUT - | Out | 18 | Tx CLK OUT+ | Out |
| 6 | Tx OUT 3- | Out | 19 | Tx OUT 3+ | Out |
| 7 | Camera Cont+ | In | 20 | Camera Cont- | In(RS-232) |
| 8 | N/C (SerTFG-) | | 21 | N/C (SerTFG+) | |
| 9 | VINIT- (ccl1-) | In | 22 | VINIT+(ccl1+) | In |
| 10 | INTEG/ROI+(ccl2+) | In | 23 | INTEG/ROI-(ccl2-) | In |
| 11 | Ext HD-(ccl3-) | In | 24 | Ext. HD+(ccl3+) | In |
| 12 | Ext VD+ (ccl4+) | In | 25 | Ext VD- (ccl4-) | In |
| 13 | GND | | 26 | GND | |

Camera Link Signal Assignment to Channel Link Chip (Base Configuration)

| | | | |
|---|---|---|---|
| Tx IN0 | Data A0 (LSB) | Tx IN14 | Data B5 (B9) |
| Tx IN1 | Data A1 | Tx IN15 (C0) | Data Res (B0) |
| Tx IN2 | Data A2 | Tx IN16 (C6) | Data Res (B6) |
| Tx IN3 | Data A3 | Tx IN17 (C7) | Data Res (B7) |
| Tx IN4 | Data A4 | Tx IN18 (C1) | Data Res (B1) |
| Tx IN5 | Data A7 (8-bit MSB) | Tx IN19 (C2) | Data Res (B2) |
| Tx IN6 | Data A5 | Tx IN20 (C3) | Data Res (B3) |
| Tx IN7 | Data B0 (A8) | Tx IN21 (C4) | Data Res (B4) |
| Tx IN8 | Data B1 (A9) | Tx IN22 (C5) | Data Res (B5) |
| Tx IN9 | Data B2 (nc) | Tx IN23 | Reserved |
| Tx IN10 | Data B6 (nc) | Tx IN24 | LDV |
| Tx IN11 | Data B7 (nc) | Tx IN25 | FDV |
| Tx IN12 | Data B3 (nc) | Tx IN26 | Reserved |
| Tx IN13 | Data B4 (B8) | Tx IN27 | Data A6 |

( ) 10-bit x 2 option, Res: Reserved

Note: CLK: data clock, LDV: Line data valid, FDV: Frame data valid, INTEG: Integration control, VINIT: Async Trigger Input.
Camera Control is available with RS-232 version and LVDS, RS-644 control




**12-Pin Connector**

| | | | |
|---|---|---|---|
| 1 | GND (power) | 7 | VD in* |
| 2 | +12V | 8 | STROBE |
| 3 | GND (analog) | 9 | HD in* |
| 4 | Video out ‡ | 10 | RXD(RS232)* |
| 5 | GND (digital) | 11 | INTEG/ROI* |
| 6 | VINIT in* | 12 | TXD(RS232)* |

‡ Channel "A" only *Optional

**Shutter Control**

| | Manual | Async |
|---|---|---|
| 0 | no shutter (1/15) | no shutter (1/15) |
| 1 | 1/60 | 1/16,000 |
| 2 | 1/125 | 1/8,000 |
| 3 | 1/250 | 1/4,000 |
| 4 | 1/500 | 1/2,000 |
| 5 | 1/1,000 | 1/1,000 |
| 6 | 1/2,000 | 1/500 |
| 7 | 1/4,000 | 1/250 |
| 8 | 1/8,000 | 1/125 |
| 9 | 1/16,000 | Ext. pulse width control |

## Specifications

| | |
|---|---|
| Imager | *1.2" progressive scan interline transfer CCD* |
| Active Area | *15.15mm x 15.15mm* |
| Active Pixels | *2048 (H) x 2048 (V)* |
| Cell Size | *7.4µm x 7.4µm* |
| Display Mode (Active Pixels) | *2048 (H) x 2048 (V) @ 15 Hz*<br>*2048 (H) x 1000 (V) @ 28 Hz (partial scan)*<br>*2048 (H) x 500 (V) @ 50 Hz*<br>*2048 (H) x 250 (V) @ 80 Hz* |
| Sync | *Internal/external auto switch*<br>*HD/VD, 4.0 Vp-p impedance 4.7 KΩ*<br>VD=14.79 Hz ± 2%, non-interlace<br>HD=30.78 kHz ± 2% |
| Data clock output | *40.00 MHz* |
| Resolution | *Digital: 2048 (H) x 2048(V),*<br>*Analog: over 800 TV lines (H) x 1600 TV lines (V)* |
| S/N ratio | *48 dB min.* |
| Min. illumination | *1.0 lux, f=1.4 (no shutter) @ 15 fps*<br>*Sensitivity: 13µ V/e-* |

| | |
|---|---|
| Video output | *Analog: 714mV, 75Ω (900 mV* white clip), ChA only<br>Digital output: 8-bit x 2 Camera Link<br>10-bit x 2 Camera Link optional |
| AGC | *OFF* |
| Gamma | *Programmable LUT (1.0 std)* |
| Lens mount | *C-mount (use > 1" format lenses)* |
| Power req | *12V DC* ± 10%, 600mA (current measured at 25°) |
| Operating temp | *-10°* C to 45°C |
| Vibration | *7 Grms (10 Hz to 2000 Hz) Random* |
| Shock | *70G* |
| Size (W x H x L) | *50.8mm x 50.8mm x 81.5mm* |
| Weight | *152 grams, 5.4 oz (without tripod)* |

| MUST BE ORDERED SEPARATELY | |
|---|---|
| Opt. Functions | *Adjustable back-focus front end, 10-bit output (no LUT operable)* |
| Opt Accessories | |
| I/O | *Camera Link digital output cable 26CL-02-26 (2m), 26CL-05-26 (5m)* |
| Power cable | *12P-02S* |
| Power supply | *PD-12UUP series (includes power connector)* |

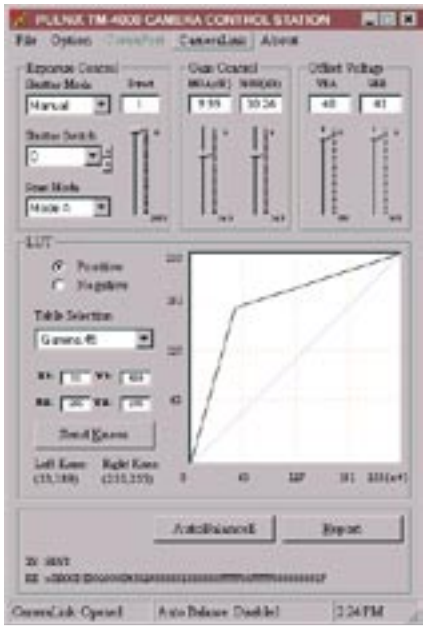
** Image quality will degrade with increasing temperature.*

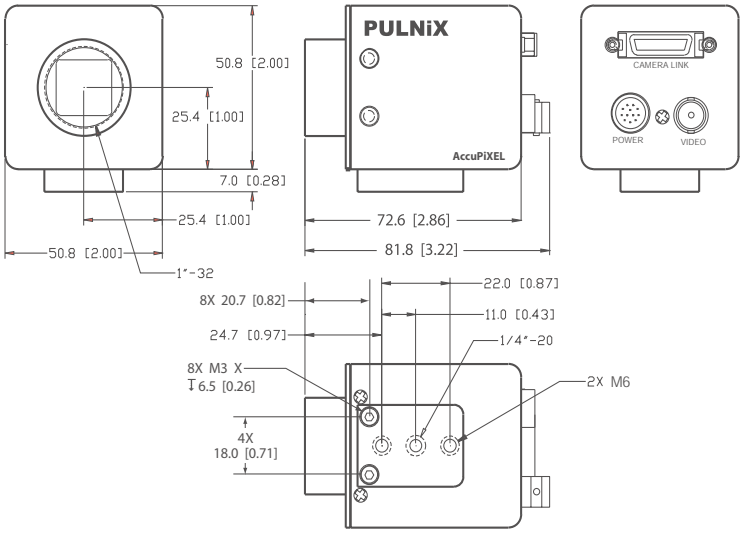
## Graphical User Interface

A user-friendly GUI (graphical user interface) is provided. This interface allows users to control the following functions of the TM-4000CL camera:

- **Shutter control for manual async. and pulse-width control**
- **Gain control**
- **Offset Control**
- **Save settings**
- **Load settings**
- **Report settings**
- **LUT setting and graphic display**
- **Scanning mode selection and Option selections**
- **Channel Auto Balancing**

Camera parameters can be uploaded from the PC to the camera. Once these parameters are stored in EEPROMs, an instantaneous change from one setting to another can be done with a delay of few frames in between.





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PULNiX
www.jaipulnix.com

# PULNiX
# Camera Link™ Cameras


Camera Link is a new digital transmission method, designed by vision product manufacturers specifically for the machine vision industry, in answer to customer requests. It is an easy way to connect digital cameras to frame grabbers.

Camera Link is a camera-to-frame grabber interface specification based on an implementation of Channel Link™ technology. It includes hardware (cable connectors), & data transmission as well as camera control and asynchronous serial communications all on a single cable. Now, only two connections (power and Camera Link) are required to operate the camera.

The specification was developed through an initiative headed by PULNiX America, Inc. Camera Link defines a single connector for both the frame grabber and the camera. This insures that all products bearing the Camera Link logo are interchangeable with each other. The official Camera Link logo is shown to the right.

As a standard that has been defined by industry members, Camera Link provides the following benefits:

- **Real-time signaling:** Camera Link supports real-time signaling. Camera Link cameras accept signals including asynchronous reset (Vinit), HD, VD, and integration through the Camera Link cable, without latency (delay).
- **High data rates:** A base configuration Camera Link interface can handle 1.2Gbps of data. The technology used in Camera Link has a maximum data rate of 3.5Gbps, insuring solutions for tomorrow's applications.
- **Flexibility:** Camera Link is independent of imager resolution, video format, and frame rate. In contrast, some other digital transmission standards are set for specific pre-defined video formats.
- **Platform independence:** Camera Link is a hardware specification designed by camera and frame grabber manufacturers specifically for the Machine Vision industry. The frame grabber software must be Windows™ 9X/2000 compatible, but is independent of support from third parties like Microsoft, Apple, or Intel.

Camera Link℠ is a registered copymark of the AIA

- **Simple interface:** Only two connections are required to interface a camera and frame grabber: Power and Camera Link. Cameras and frame grabbers can be easily interchanged using the same cable.
- **Standardized cable assembly:** Camera Link specifies a standard cable assembly. This eliminates the need for manufacturers to provide custom cables, and allows customers to take advantage of lower cable prices. In addition, the technology used in Camera Link reduces the number of wires required to transmit data, allowing for thinner cables, which are more robust and less prone to breakage. Various cable lengths are available up to 10m.
- **Extensive application software support from frame grabber and vision software companies:** Machine vision applications require robust and field-proven software. Camera Link is a quick and simple way for users to standardize their systems for existing applications without having to verify new software.
- **Long-term, stable supply:** Channel Link technology is committed to providing long-term support to the telecommunications industry. Unlike most consumer products, the basic architecture will remain stable for many years to come.


Channel Link™ is a registered trademark of National Semiconductor.

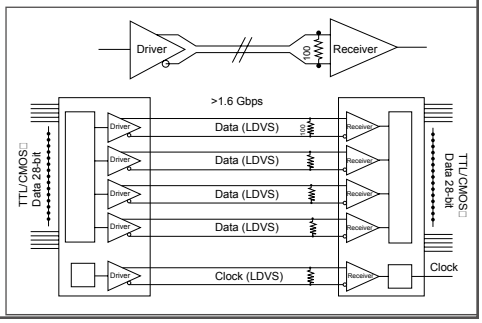
Windows 2000™ is a registered trademark of Microsoft Corporation.

## Channel Link Technology

The heart of Camera Link is Channel Link, a data transmission method by National Semiconductor. Channel Link is made up of a receiver chip and a transmitter chip. This chipset is used to transmit digital data. This technology offers many advantages to machine-vision applications over the previous method, namely, RS-644 (LVDS format of RS-422).

LVDS (Low Voltage Differential Signaling) has become the most common means to transmit digital data in recent years. This method, however, has several major drawbacks. LVDS requires a pair of wires for transmission of each data bit, creating bulky cables prone to breakage if stressed. Also, the maximum data transmission rate of LVDS is 400 Mbps, fast enough for today's applications, but limiting for tomorrow's requirements. Channel Link takes LVDS to the next level.

Channel Link uses LVDS standards to transmit data. Far fewer wires, however, are needed to transmit the data. A Channel Link transmitter will convert 28 bits of data into a format that can be transmitted over 4 parallel lines. A transmit clock over a fifth line finishes the requirements for Channel Link transmission. The diagram to the right shows how just five pairs of wire are able to transmit data that would require 56 wires using standard LVDS methods.



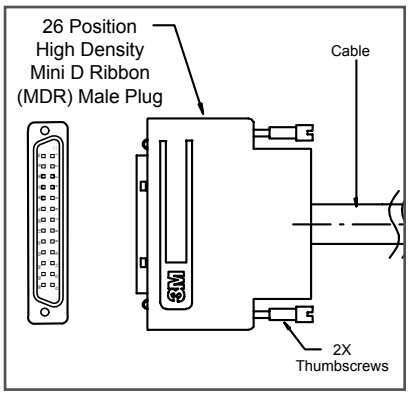

## Camera Link Connector and Cable Configurations

A single Camera Link connection provides the following information on an MDR connector with 26 pins.

| | |
|---|---|
| Image data and timing | 4 pairs |
| | 1 pair transmission clock |
| Serial communication | 1 pair transmit |
| | 1 pair receive |
| Camera Control | 4 signal pairs |

This configuration will transfer up to 28 bits of data. For applications that require more bandwidth, additional Camera Link connections can be used.

There are 3 configurations – base, medium and full. Please visit the PULNiX web site for detailed specifications of Camera Link.




**Camera Link Cable**

***Note:*** *The MDR-26 cable assembly is manufactured by 3M Corporation.*

## Camera Link Cable Ordering Information

Camera Link cables are available from multiple vendors.

| JAI PULNiX P/N | 3M | Intercon I | Length |
|---|---|---|---|
| ***Molded Cables*** | | | |
| | 14T26-SZLB-100-0LC | CLCP-1.0-p | |
| 26CL-02-26 | 14T26-SZLB-200-0LC | CLCP-2.0-p | |
| | 14T26-SZLB-300-0LC | CLCP-3.0-p | |
| | 14T26-SZLB-500-0LC | CLCP-5.0-p | |
| | 14T26-SZLB-700-0LC | CLCP-7.0-p | |
| | 14T26-SZLB-A00-0LC | CLCP-10-p | |
| | 14T26-SZLB-450-0LC | CLCP-4.5-p | |
| **Shell Kit Cables** | | | |
| | 14B26-SZLB-100-0LC | CLCPH-1.0-p | |
| | 14B26-SZLB-200-0LC | CLCPH-2.0-p | |
| | 14B26-SZLB-300-0LC | CLCPH-3.0-p | |
| | 14B26-SZLB-450-0LC | CLCPH-4.5-p | |
| | 14B26-SZLB-500-0LC | CLCPH-5.0-p | |
| | 14B26-SZLB-700-0LC | CLCPH-7.0-p | |
| | 14B26-SZLB-A00-0LC | CLCPH-10-p | |

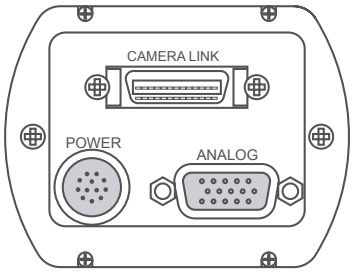
## Connector and Pin Configurations

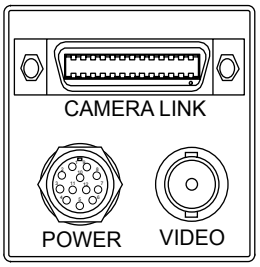
### Camera Link Connector (MDR 26-pin connector)

Rear Panel top view

### Rear Panel

TMC-6700CL/TMC-1000CL AccuPiXEL™ Series

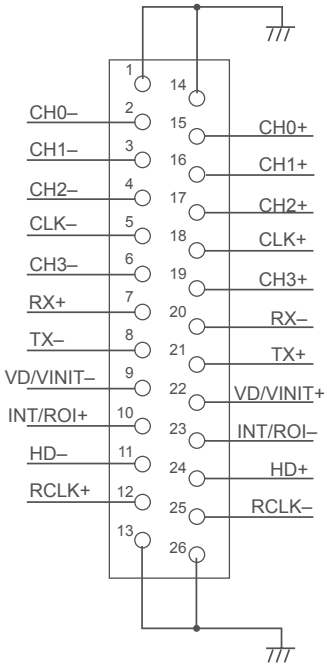



### MDR 26-pin Connector 10226-6212VC

| Pin# | Description | I/O |
|---|---|---|
| 1 | GND (shield) | |
| 2 | X0- (CH0-) | Out |
| 3 | X1- (CH1-) | Out |
| 4 | X2- (CH2-) | Out |
| 5 | Xclk- (CLK-) | Out |
| 6 | X3- (CH3-) | Out |
| 7 | SerTC+ (Rx+) | In |
| 8 | SerTFG- (Tx-) | Out |
| 9 | CC1- (Vinit/VD-) | In |
| 10 | CC2+ (Integ/ROI+) | In |
| 11 | CC3- (HD-) | In* |
| 12 | CC4+ (RCLK+) | In** |
| 13 | GND | |
| 14 | GND (shield) | |
| 15 | X0+ (CH0+) | Out |
| 16 | X1+ (CH1+) | Out |
| 17 | X2+ (CH2+) | Out |
| 18 | Xclk+ (CLK+) | Out |
| 19 | X3+ (CH3+) | Out |
| 20 | SerTC- (Rx-) | In (LVDS or RS-232) |
| 21 | SerTFG+ (Tx+) | Out |
| 22 | CC1+ (Vinit/VD+) | In |
| 23 | CC2- (Integ/ROI-) | In |
| 24 | CC3+ (HD+) | In* |
| 25 | CC4- (RCLK-) | In** |
| 26 | Inner shield | |

The 26-pin Connector Pin Assignment
(Camera Side)




Node description:
CH0: Data B0, A5, A4, A3, A2, A1, A0
CH1: Data C1, C0, B5, B4, B3, B2, B1
CH2: Data DVAL, FVAL, LVAL, C5, C4, C3, C2
CH3: Data SPARE, C7, C6, B7, B6, A7, A6
CLK: Data clock
RX, TX: Serial communication, RX = Ser to Cam□
□ TX = Ser to FG
VD/VINIT: Ext. VD in or VINIT (Triger) in
INT/ROI: Integration control in or □
□ Read-Out-Inhibit in
HD: External HD in
RCLK: External read clock in

* *HD, VD for external sync input. (Please contact PULNiX for Ext. HD input)*
** *RCLK is reserved for read clock input.*

### Camera Link Signal Assignment to Channel Link Chip (RGB 8-bit x 3)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tx IN0 | Data R0 (LSB) | Tx IN8 | G1 | Tx IN16 | B6 | Tx IN24 | LDV |
| Tx IN1 | Data R1 | Tx IN9 | G2 | Tx IN17 | B7 | Tx IN25 | FDV |
| Tx IN2 | Data R2 | Tx IN10 | G6 | Tx IN18 | B1 | Tx IN26 | LPULSE |
| Tx IN3 | Data R3 | Tx IN11 | G7 | Tx IN19 | B2 | Tx IN27 | R6 |
| Tx IN4 | Data R4 | Tx IN12 | G3 | Tx IN20 | B3 | Tx CLK | Data clock |
| Tx IN5 | Data R7 (MSB) | Tx IN13 | G4 | Tx IN21 | B4 | | |
| Tx IN6 | Data R5 | Tx IN14 | G5 | Tx IN22 | B5 | | |
| Tx IN7 | Data G0 | Tx IN15 | B0 | Tx IN23 | (YCC CLK) | | |

**Note1:** CLK: data clock, LDV: Line data valid, FDV: Frame data valid, INTEG: Integration control, VINIT: Async Trigger Input, ROI: Read-out-inhibit.
**Note2:** Data $R_{0-7}$ is defined as $A_{0-7}$, Data $G_{0-7}$ is defined as $B_{0-7}$. Data $B_{0-7}$ is defined as $C_{0-7}$. For 8-bit B/W, only $A_{0-7}$ is used. For 8-bit x 2 $A_{0-7}$ and $B_{0-7}$ are used.
**Note3:** Camera control via 12-pin connector (RS-232) is available as an option.

# Camera Link Camera Models

| Camera models B/W Cameras | CCD (In) | Resolution | Frame rate (frame/sec.) | Data Clock (MHz) | Data | Analog video | Size (HxWxL mm) |
|---|---|---|---|---|---|---|---|
| TM-6760CL | 1/2 | 648 x 484 | 60/30 | 25.49/12.75 | Ch-A 8-bit | BNC: VGA video | 44 x 44 x 64 |
| TM-6710CL | 1/2 | 648 x 484 | 120/60 | 25.49/12.75 | Ch-A & B 8-bit x 2 | BNC: 120 fps @ 50MHz | 39 x 46 x 140 |
| TM-1400CL | 1/2 | 1392 x 1040 | 20 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-1320A-15CL | 2/3 | 1300 x 1030 | 15 | 25.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-1320A-24CL | 2/3 | 1300 x 1030 | 24 | 40.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-1325CL | 2/3 | 1392 x 1040 | 15/30 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-1020-15CL | 1 | 1008 x 1018 | 15 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-2016-8CL | 1 | 1920 x 1080 | 8 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-2016-15CL | 1 | 1920 x 1080 | 15 | 40.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TM-4000CL | 1.2 | 2048 x 2048 | 15 | 40.0 | 8-bit x 2 | BNC: progressive scan | 51 x 51 x 82 |
| Color Cameras | | | | | | | |
| TMC-6700CL | 1/2 | 648 x 484 | 60 | 25.49 | Ch-R,G,B 8-bit x 3 | Dsub: RGB video VGA video | 51 x 67 x 117 |
| TMC-1000CL | 1 | 1008 x 1018 | 15 | 20.0 | Ch-R,G,B 8-bit x 3 | Dsub: RGB video progressive scan | 51 x 67 x 117 |
| TMC-6760CL$^{\Delta}$ | 1/2 | 648 x 484 | 60 | 25.49/12.75 | Ch-A 8-bit | BNC: VGA video | 44 x 44 x 64 |
| TMC-6710CL | 1/2 | 648 x 484 | 120 | 25.49 | Ch-A & B 8-bit x 2 | BNC: 120 fps @ 50MHz VGA video | 39 x 46 x 140 |
| TMC-1400CL$^{\Delta}$ | 1/2 | 1392 x 1040 | 20 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-15CL$^{\Delta}$ | 2/3 | 1300 x 1030 | 15 | 25.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-24CL$^{\Delta}$ | 2/3 | 1300 x 1030 | 24 | 40.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1325CL | 2/3 | 1392 x 1040 | 15/30 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1020-15CL$^{\Delta}$ | 1 | 1008 x 1018 | 15 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-2016-8CL$^{\Delta}$ | 1 | 1920 x 1080 | 8 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-4000CL$^{\Delta}$ | 1.2 | 2048 x 2048 | 15 | 40.0 | Ch-A & B 8-bit x 2 | BNC: progressive scan | 51 x 51 x 82 |

*$^{\Delta}$ AccuPiXEL color cameras require software interpolation.*

Please contact PULNiX for availability. For detailed camera specifications, please refer to the standard camera data sheet for each model.

*For product updates and data sheets, see our web site:*

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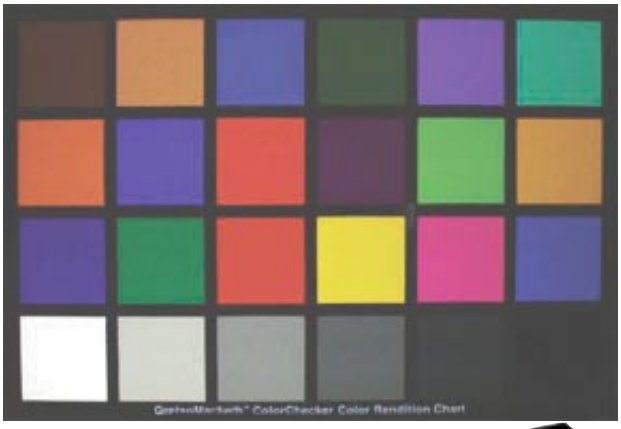
# PULNiX Color AccuPiXEL™

## New Product Summary

- High-resolution, high-speed progressive scan interline transfer CCD imagers
- Digital Camera Link, RS-644 (LVDS) output and analog output
- Bayer color filter arrays
- Maximum dynamic range control with built-in look-up table (Gamma, knee, user parameters)
- Full-frame integration, partial scan, two-row binning
- Smaller, lightweight housing with high-rel connector
- Full-frame shutter up to 1/16,000 sec.
- Asynchronous reset, no-delay shutter, read-out-inhibit control
- RS-232 or Camera Link external control
- Excellent color reproduction with various color interpolation software



Actual image taken with the TMC-1320


## General Description

The PULNiX AccuPiXEL series color cameras are high-resolution, high-speed progressive scan CCD cameras. The interline transfer, progressive scan CCD permits full vertical and horizontal resolution of images acquired at very high shutter speeds. The electronic shutter, which has speeds to 1/16,000 sec., can be reset asynchronously by external pulse control. Uniform square pixels provide superior image definition in any orientation. On-chip micro lenses mean increased sensitivity.

## Color Filter Array

PULNiX AccuPiXEL cameras use Bayer CFA (color filter array) as their standard primary color filter. This filter provides the most popular color interpolation supported by numerous software suppliers.

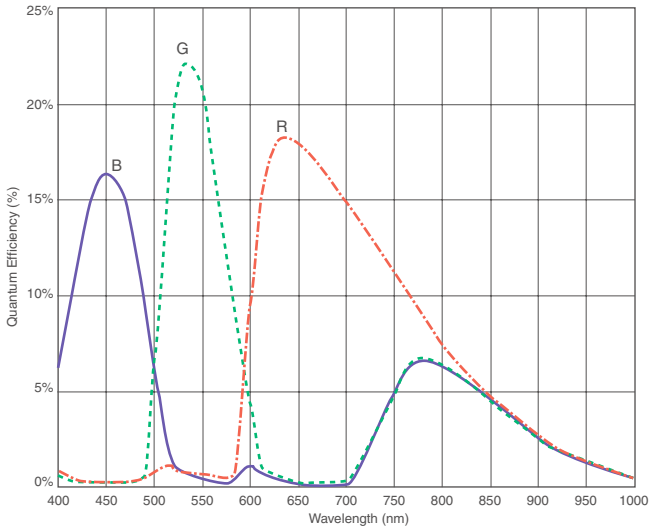
The digital format, either Camera Link or RS-644, allows the camera to output accurate pixel data, including the color information. When the data is stored in the frame buffer of a frame grabber or computer, the color information is easily manipulated to restore the original color images. Because the color filter array contains only a single R, G or B color in each pixel, the restored image has to fill in colors in the missing pixel locations. The software uses neighboring pixel information to “guess” the missing colors to make smooth, clear images. This is called “Color Interpolation.” Today’s high-speed computers allow such color interpolation to be done almost in real time. Because these cameras do not contain internal color-processing circuitry, they are smaller and less expensive than full-function color cameras.

## Bayer Color Filter Array (CFA)

The Bayer CFA is an R, G, B primary color filter array. This is the most widely accepted CFA for the single-chip CCD progressive scan format. This type of array layout has a specific order for each color’s pixels. Since the human eye’s resolution and color recognition are highest at green, the CFA contains two greens per each red and blue.

It is critical for the frame grabber and color interpolation to know where the individual color pixels exist relative to sync (LDV and FDV) timing.

This requirement makes digital output the preferred choice, because the timing relationships are very accurate.



## Starting Pixel Configuration

All manufacturers produce identical Bayer CFAs, but there are slight differences between the CCDs produced by different manufacturers. The first line is generally R and G, except for the Kodak CCD, which starts with G. The Sony CCD starts with R. The camera timing can be adjusted to start with either G or R by skipping the very first pixels at each lines. The majority of color interpolation software can select between a variety of pixel relations, such as R/G start or G/R start, as well as G/B start and B/G start. Once the correct scanning is configured, the rest of the interpolation will be exactly the same.

Please contact JAI PULNiX for further information regarding CCD manufacturers.

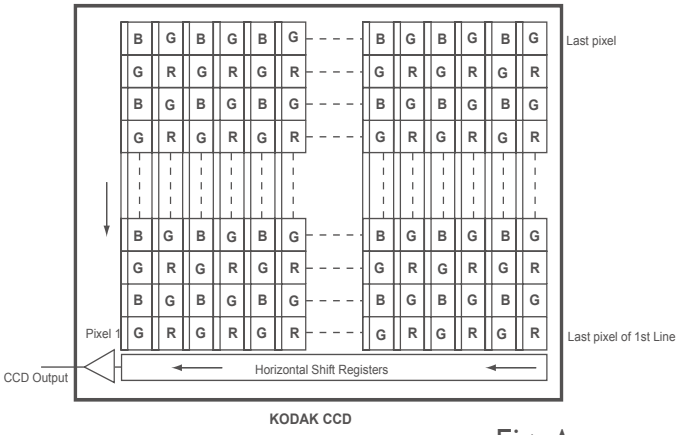



Fig. A

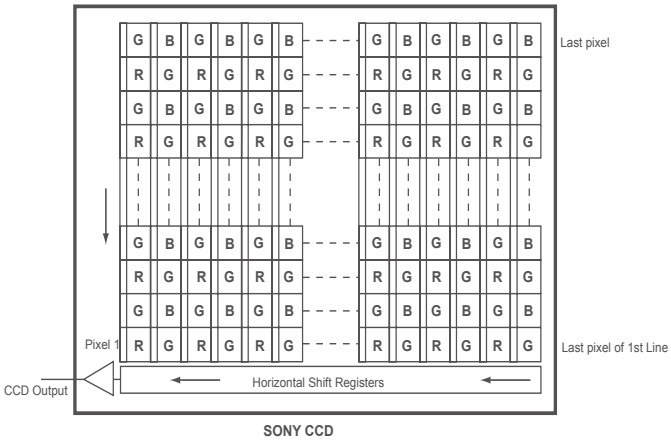



Fig. B

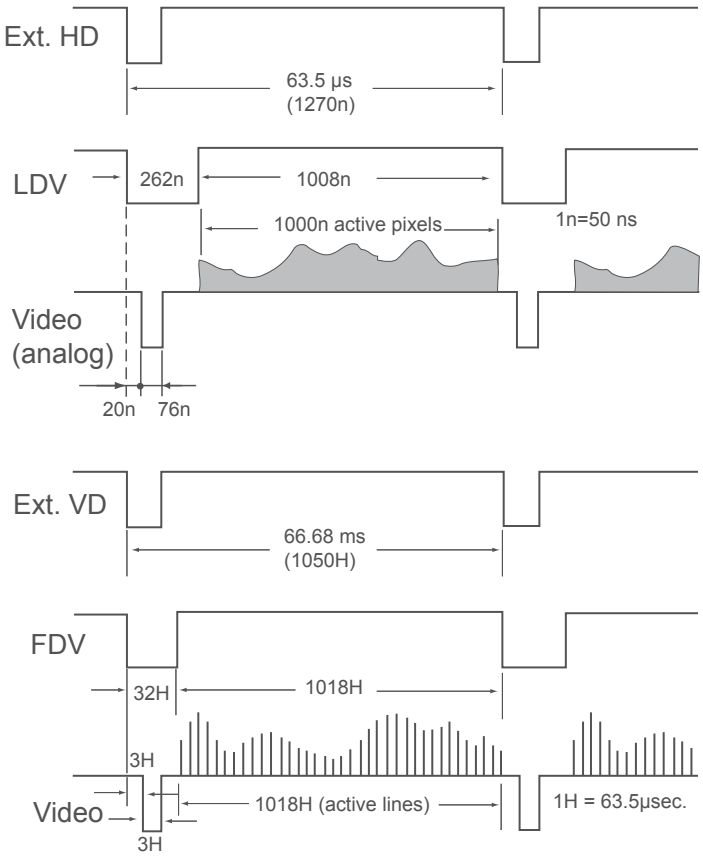
## Sync and Data

The individual color data is exactly the same as the pixel data. This means that the timing relationships of the color cameras are also the same as of the B/W cameras.

For a detailed timing chart, please refer to each B/W camera's data sheet and manual.

If the frame grabber has a standard B/W configuration file, then AccuPiXEL color cameras can use that configuration file to operate. The configuration file may vary, depending on whether the output is standard (RS-644) or Camera Link. Please consult JAI PULNiX, or your frame grabber supplier for compatibility information.

The following diagram is an example of the TMC-1020-15 (same as TM-1020-15).




It is important to meet the exact starting pixel at LDV and the starting line of FDV. If the starting pixel or line is shifted due to the image capture configuration, then the interpolation software can be adjusted for the correct starting point. In figure A, if the first pixel is shifted (missed), the color interpolation should start with R-G. If the first line is missed in A, the interpolation order will be B-G.

## Camera Functions

AccuPiXEL color cameras perform all functions the same way as B/W cameras. However, because of color characteristics, the following issues are different:

1. Two-row binning scan

When two rows are mixed in the CCD, the Bayer color is no longer valid. It provides color information but cannot be interpolated as a Bayer CFA.

2. LUT (Look-up Table)

LUT is a powerful tool to adjust the dynamic range as well as color dynamic range. Since human color perception is non-linear, LUT selection can help optimize color contrast by selecting the LUT value. Gamma 0.45 is logarithmic and is closed to human perception.

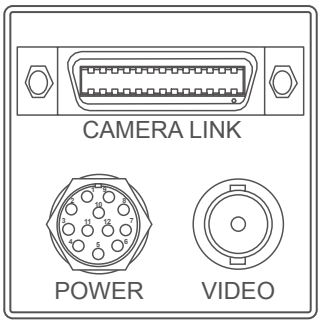
When LUT is selected, black-level adjustment must be more accurate than for B/W cameras.

For a detailed timing chart, please refer to the standard AccuPiXEL camera data sheet, or contact JAI PULNiX.

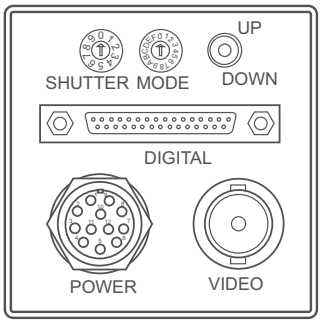
## Basic Mode Selections (For Non-CL Versions)*

| | Mode Switch | Up/Down Switch | Functions |
|---|---|---|---|
| 0 | Switch Disabled | Switch Disabled | None |
| 1 | Set Gain | Up / Down | Change gain |
| 2 | Set Vtop (A/D) | Up / Down | Change A/D ref. top |
| 3 | Set Vbottom (A/D) | Up / Down | Change A/D ref bottom |
| 4 | Gain Selection #1 | Up: 9dB, Down: 12dB | Lower gain selection |
| 5 | Gain Selection #2 | Up: 18dB, Down: 22dB | Higher gain selection |
| 6 | Linear LUT | Up | Back to linear table |
| 7 | Knee Selection | Up / Down (Scroll) | Scroll 10 different LUTs |
| 8 | Async Reset Mode | Up: Normal, Dwn: Async | Async and normal shutter |
| 9 | Factory Default Recall | Up / Down: Recall | Factory setting |
| A | Power up Setting | Up: Recall, Dwn: Save | Power up page setting |
| B | User Page Storage#1 | Up: Recall, Dwn: Save | User page storage setting |
| C | User Page Storage#2 | Up: Recall, Dwn: Save | User page storage setting |
| D | Direct Shutter Control | Up / Down | Shutter speed increment by 1H |
| E | Scan Format2 | Up: Optional, Dwn: Binning | Two-row binning selection |
| F | Scan Format1 | Up: Normal, Dwn: Optional | Custom option scanning |

**These mode descriptions may change from camera model to camera model slightly. The same functions are controlled by RS-232 or Camera Link software.*




Camera Link model rear panel




LVDS model rear panel.
*Does not apply to TMC-4000*

## Interpolation Software

Major frame grabber manufacturers with digital capability (Camera Link, RS-644) provide color interpolation software. Some independent image process software suppliers provide software as well.

The following table lists a few examples.

| Manufacturer | Frame Grabber | Software |
|---|---|---|
| Matrox | Meteor II Digi, CL | MIL |
| Bitflow | Road Runner CL | Bay View |
| Coreco | T64 | Application software |
| Data Cube | MaxRevolution | Visual Chip Studio |
| Epix | PIXCI | Application software |
| Euresys | GrabLink | Easygrab<br>EasyColor |
| Matrix Vision | MV-Titan/CL | Impact |
| Silicon Software | microEnable III | microDisplay |

## Color Interpolation

The Bayer pattern color filter array (CFA) consists of R, G, and B primary colors. Each pixel represents one of three colors. In order to display or print color images, the signal has to be converted to RGB output, which has three independent channels (outputs) and sync signals.

Color interpolation software or firmware performs the color preprocessing by filling the missing color pixels with neighboring pixels. It then separates the stream of data, (8-bit or 10-bit) into 3 (RGB) data (8-bit x 3) and adds the color matrix to adjust and balance each of the R,G, and B channels (white balance or color balance).

| | | |
|---|---|---|
| Green | Red | Green |
| Blue | Green | Blue |
| Green | Red | Green |

The image quality depends on the camera's own pixel data (including pixel data independency from neighboring pixels, noise and color filter), and interpolation of the software algorithm such as 3 x 3 interpolation, 2 x 2 interpolation, color matrix, white balance capability, etc.

All AccuPiXEL color cameras are carefully designed for maximum color performance. JAI PULNiX strongly suggests that you use digital output for the best performance.

Some software is used on board (FPGA or DSP) to perform the interpolation. Other software simply uses the host computer's memory and CPU. The process speed may vary depending on the architecture and speed of the computer.

## Color AccuPiXEL Cameras

| Camera models AccuPiXEL Color | CCD | Resolution | Frame Rate (frame/sec) | Data Clock (NHz) | Data | Analog Video | Size (HxWxL in mm) |
|---|---|---|---|---|---|---|---|
| TMC-6760 | 1/2” | 648 x 484 | 60 | 25.0/12.50 | 8-bit | BNC: VGA video | 44 x 44 x 64 |
| TMC-6760CL | 1/2” | 648 x 484 | 60 | 25.0/12.50 | Ch-A 8-bit | BNC: VGA video | 44 x 44 x 64 |
| TMC-1400 | 1/2” | 1392 x 1040 | 15/30 | 33.3 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1400CL | 1/2” | 1392 x 1040 | 15/30 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-15 | 2/3” | 1300 x 1030 | 15 | 25.0 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-15CL | 2/3” | 1300 x 1030 | 15 | 25.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-24 | 2/3” | 1300 x 1030 | 24 | 40.0 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1320A-24CL | 2/3” | 1300 x 1030 | 24 | 40.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1325 | 2/3” | 1392 x 1040 | 15/30 | 33.3 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1325CL | 2/3” | 1392 x 1040 | 15/30 | 33.3 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1020A-15 | 1” | 1008 x 1018 | 15 | 20.0 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-1020A-15CL | 1” | 1008 x 1018 | 15 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-2016-8 | 1” | 1920 x 1080 | 8 | 20.0 | 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-2016-8CL | 1” | 1920 x 1080 | 8 | 20.0 | Ch-A 8-bit | BNC: progressive scan | 44 x 44 x 64 |
| TMC-4000CL | 1.2” | 2048 x 2048 | 15 | 40.0 | Ch-A & B 8-bit x 2 | BNC: progressive scan | *51 x 51 x 82* |

CL: Camera Link

Please contact PULNiX for availability. For detailed camera specifications, please refer to the standard camera data sheet for each model.

***For product updates and data sheets see our web site:***

***www.jaipulnix.com***

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