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## KAF-4320 Evaluation Timing Specification

### Altera Code Version Description

The Altera code described in this document is intended for use in the ADS-93x Timing Board. The code is written specifically for use with the following system configuration:

### EVAL BOARD USER'S MANUAL

**Table 1. SYSTEM CONFIGURATION**

| Evaluation Board Kit:     | PN 4H0475                     |
|---------------------------|-------------------------------|
| Timing Generator Board    | 3E8290 (ADS-933 3 MHz)        |
| KAF-4320 CCD Imager Board | 3E8371                        |
| Framegrabber Board        | National Instruments PCI-1424 |

### ALTERA CODE FEATURES / FUNCTIONS

The Altera Programmable Logic Device (PLD) performs the following functions:

#### Timing Generator

The PLD serves as a state machine based timing generator whose outputs interface to KAF-4320, the ADS-933 A/D converter, and the PCI-1424 Framegrabber. The behavior of these output signals is dependent upon the current state of the state machine. External digital inputs, as well as jumpers on the board can be used to set the conditions of certain state transitions (See Table 2). In this manner, the board may be run in any of the following operating modes:

- Continuous Capture Mode
- Triggered Capture Mode
- Internally or Externally Controlled Integration Timing Modes

- CCD Output Amplifier Enable/Disable during Integration Time Mode Option
- 2 x 2 Binning Mode Option

#### Timing Signal Adjustments

The PLD contains addressable registers that can be accessed via the digital input interface to adjust certain timing conditions on the board. The pulse-width and position of the H1, H2, RESET, CLAMP and AD\_CLK can be adjusted in increments of  $1/16^{\text{th}}$  of a pixel time. When operating in internally controlled integration time mode, the Integration time can be adjusted to be any one of 32 pre-programmed times.

Upon power up, or when the BOARD\_RESET button is depressed, the PLD will reset these registers to their original (default) values.

**ALTERA CODE I/O**

**Table 2. INPUTS**

| Symbol         | Description                                                                                                                                                          |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| POWER_ON_DELAY | The rising edge of this signal clears and re-initializes the PLD                                                                                                     |
| SYSTEM_CLK     | 48 MHz clock, 16X the desired pixel clock rate                                                                                                                       |
| INTEGRATE_CLK  | 100 Hz clock, Provides 10 ms unit integration time                                                                                                                   |
| SCLOCK         | Digital input, Used as the external trigger in Triggered Capture Mode                                                                                                |
| SLOAD          | Not Used                                                                                                                                                             |
| SDATA          | Not used                                                                                                                                                             |
| JMP0           | Output mode Control:<br>HIGH = Triggered Capture Mode<br>LOW = Continuous Capture Mode                                                                               |
| JMP1           | Binning Mode Control:<br>HIGH = 2 X 2 Binning<br>LOW = No Binning                                                                                                    |
| JMP2           | Internal/External Integration Mode Control:<br>HIGH = External Integration Control using DIO15<br>LOW = Pre-set Integration Time selected by INT MODE register value |
| JMP3           | Output Amplifier Enable Mode Control:<br>HIGH = Disable amplifier during integration time.<br>LOW = Always enable amplifier.                                         |
| DIO[1..0]      | Multiplexed CCD Video control lines                                                                                                                                  |
| DIO[5..2]      | Timing PLD Register Address Select Lines                                                                                                                             |
| DIO[13..6]     | Timing PLD Register Data Select Lines                                                                                                                                |
| DIO14          | Update Register Write Strobe                                                                                                                                         |
| DIO15          | User-Defined Integration control line; bring HIGH to end Integration                                                                                                 |

**Table 3. OUTPUTS**

| Signal       | Function   | Description                                                                           |
|--------------|------------|---------------------------------------------------------------------------------------|
| Timing_Out11 | AMP_ENABLE | Control line for alternate VDD supply to CCD output amplifier during Integration Time |
| Timing_Out10 | Not Used   |                                                                                       |
| Timing_Out9  | MUX_SEL1   | CCD VOUT Multiplexer control line                                                     |
| Timing_Out8  | MUX_SEL0   | CCD VOUT Multiplexer control line                                                     |
| Timing_Out7  | V2_CLK     | KAF-4320 CCD V2 Clock                                                                 |
| Timing_Out6  | V1_CLK     | KAF-4320 CCD V1 Clock                                                                 |
| Timing_Out5  | R_CLK      | KAF-4320 CCD Reset Clock                                                              |
| Timing_Out4  | Not Used   |                                                                                       |
| Timing_Out3  | H1_CLK     | KAF-4320 CCD H1 Clocks                                                                |
| Timing_Out2  | H2_CLK     | KAF-4320 CCD H2 Clocks                                                                |
| Timing_Out1  | H1L_CLK    | KAF-4320 CCD H1L Clock                                                                |
| Timing_Out0  | Not Used   |                                                                                       |
| CLAMP        | CLAMP      | Pixel-Rate CDS Clamp Signal                                                           |
| AD_CLK       | A/D CLOCK  | ADS-933 A/D Clock (CDS Sample Signal)                                                 |
| PIX          | PIXEL SYNC | PCI-1424 Frame Grabber Pixel Rate Synchronization                                     |
| FRAME        | FRAME SYNC | PCI-1424 Frame Grabber Frame Rate Synchronization                                     |

**Table 3. OUTPUTS**

| Signal    | Function  | Description                                      |
|-----------|-----------|--------------------------------------------------|
| LINE      | LINE SYNC | PCI-1424 Frame Grabber Line Rate Synchronization |
| INTEGRATE | INT SYNC  | High During CCD Integration Time                 |

### KAF-4320 SYSTEM TIMING CONDITIONS

**Table 4. SYSTEM TIMING CONDITIONS**

| Description           | Symbol | Time  | Notes               |
|-----------------------|--------|-------|---------------------|
| System Clock Period   | Tsys   | 21 ns | 48 MHz system clock |
| Unit integration time | Uint   | 10 ms | Typical             |
| Power stable delay    | Tpwr   | 10 ms | Typical             |

**Table 5. CCD TIMING CONDITIONS**

| Description              | Symbol     | Time        | Pixel Counts | Notes                                                |
|--------------------------|------------|-------------|--------------|------------------------------------------------------|
| H1, H2, RESET period     | Tpix       | 333 ns      | 1            | 3 MHz clocking of H1, H1L, H2, RESET                 |
| VCCD delay               | Tvd        | 333 ns      | 1            | Between Hclks stopping and V1 rising edge            |
| V1, V2 Pulse Width       | TVCCD      | 30 $\mu$ s  | 90           | Between V rising edge and V falling edge             |
| Horizontal setup time    | Ths        | 10 $\mu$ s  | 30           | Between 2nd V1 falling edge and Hclks startup        |
| Vertical transfer period | Vperiod    | 100 $\mu$ s | 301          | $Vperiod = Tvd + (3 * TVCCD) + Ths$                  |
| Pixels per line          | PIX_X      | 350 $\mu$ s | 1050         | 1050 CCD pixels per line (1042 active)               |
| Lines per frame          | PIX_Y      |             | 1046         | 1046 CCD lines per frame (1042 active)               |
| Vertical flush period    | Fperiod    | 60 $\mu$ s  | 180          | Time to flush one line                               |
| Flush duration           | Flines     |             |              | Number of lines flushed = 2084                       |
| Flush delay              | Fdelay     | ~5 ms       |              | Time between last flush line and next UNIT INT clock |
| Flush time               | Ftime      | ~135 ms     |              | $Ftime = (Fperiod * Flines) + Fdelay$                |
| External Trigger delay   | Trig delay | 0–10 ms     |              | Variable due to asynchronous trigger                 |

**Table 6. ADS-933 A/D CONVERTER TIMING CONDITIONS**

| Description   | Symbol | Time   | Pixel Counts | Notes                       |
|---------------|--------|--------|--------------|-----------------------------|
| AD CLK period | Tpix   | 333 ns | 1            | 3 MHz clocking of A/D Clock |

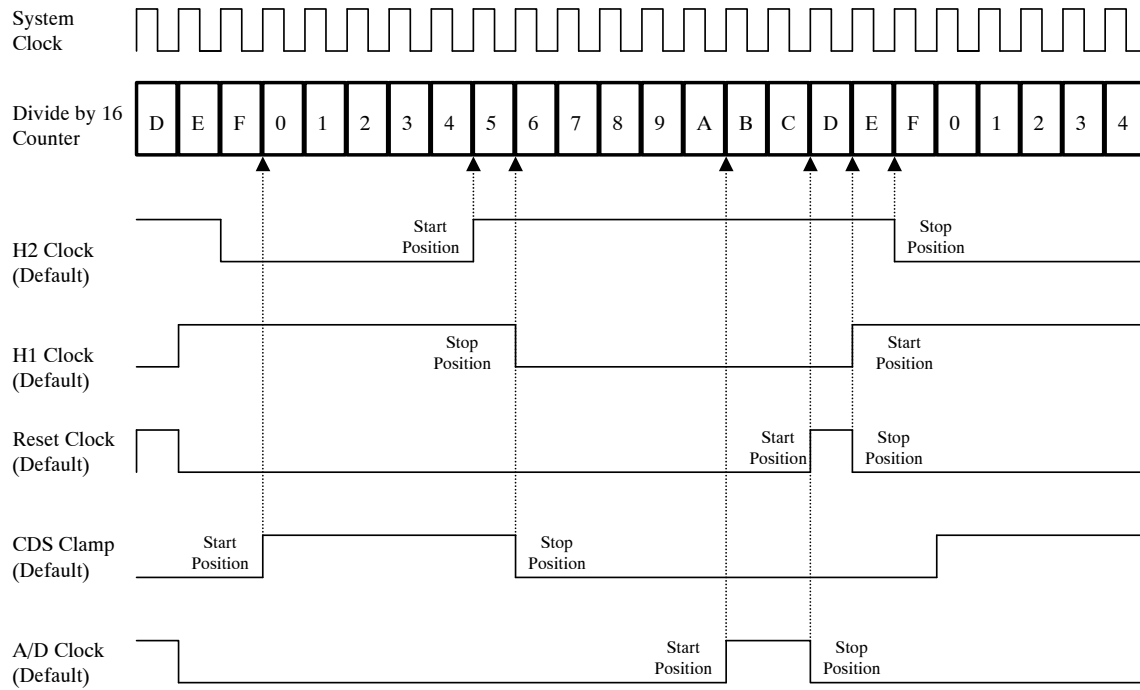
**Table 7. PCI-1424 TIMING CONDITIONS**

| Description                  | Symbol | Time   | Pixel Counts | Notes                                         |
|------------------------------|--------|--------|--------------|-----------------------------------------------|
| PIX period                   | Tpix   | 333 ns | 1            | 3 MHz clocking of PIX sync signal             |
| PIX per line                 |        |        | 1050         | Number of PIX syncs per line                  |
| 2 X 2 Binning PIX per line   |        |        | 525          | Number of PIX syncs per line in binning mode  |
| LINE per frame               |        |        | 1046         | Number of LINE syncs per line                 |
| 2 X 2 Binning LINE per frame |        |        | 522          | Number of LINE syncs per line in binning mode |

## PIXEL RATE CLOCKS GENERATION

The pixel rate clocks are derived from the system clock. They operate at  $1/16^{\text{th}}$  the frequency of the system clock. The system clock is divided down to create sixteen different time steps per pixel. Each of the pixel rate signals start and stop positions can be adjusted by loading the desired start

and stop positions into the appropriate register. In this way both the signals position and duty cycle can be adjusted. The timing of these signals is reset back to the original default positions on power-up or when the board reset button is pressed.



**Figure 1. Pixel Clock Generation Timing**

PARALLEL INTERFACE TIMING AND INTERNAL REGISTER DESCRIPTION

Table 8. INTERNAL REGISTER DESCRIPTION

| Register Name            | Address | D0             | D1 | D2 | D3  | D4            | D5  | D6 | D7  | Default Value (HEX) |
|--------------------------|---------|----------------|----|----|-----|---------------|-----|----|-----|---------------------|
| Not Used                 | 0       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 1       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 2       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 3       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 4       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 5       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 6       | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| H1 Clock Position        | 7       | Start Position |    |    |     | Stop Position |     |    |     | 6E                  |
|                          |         | LSB            |    |    | MSB | LSB           |     |    | MSB |                     |
| H2 Clock Position        | 8       | Start Position |    |    |     | Stop Position |     |    |     | F5                  |
|                          |         | LSB            |    |    | MSB | LSB           |     |    | MSB |                     |
| Reset Clock Position     | 9       | Start Position |    |    |     | Stop Position |     |    |     | ED                  |
|                          |         | LSB            |    |    | MSB | LSB           |     |    | MSB |                     |
| Clamp Position           | 10      | Start Position |    |    |     | Stop Position |     |    |     | 60                  |
|                          |         | LSB            |    |    | MSB | LSB           |     |    | MSB |                     |
| A/D Clock Position       | 11      | Start Position |    |    |     | Stop Position |     |    |     | DB                  |
|                          |         | LSB            |    |    | MSB | LSB           |     |    | MSB |                     |
| Not Used                 | 12      | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Integration Mode Setting | 13      | LSB            |    |    |     |               | MSB | X  | X   | 0                   |
| Not Used                 | 14      | X              | X  | X  | X   | X             | X   | X  | X   | X                   |
| Not Used                 | 15      | X              | X  | X  | X   | X             | X   | X  | X   | X                   |

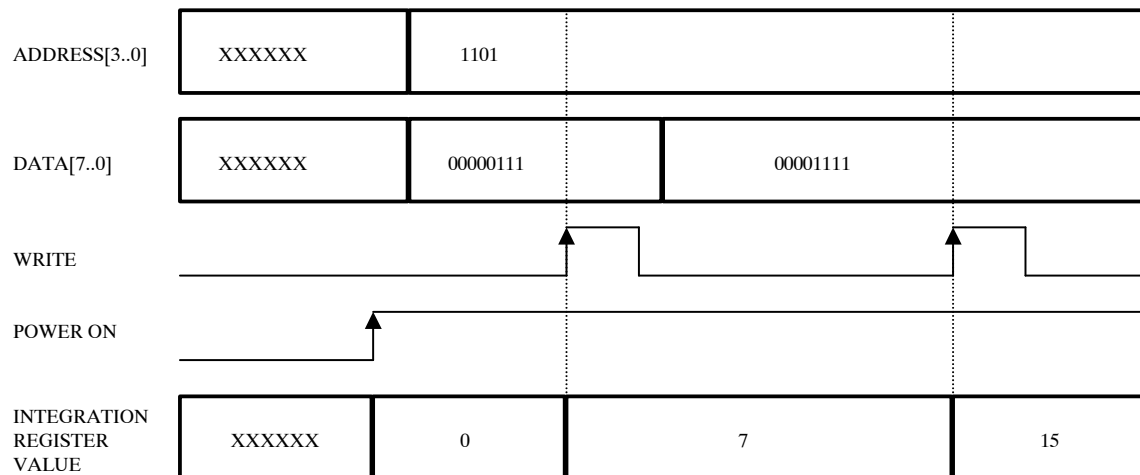


Figure 2. Internal Register Update Timing Example

## MODES OF OPERATION

The system's operating mode is selected by setting the jumpers JMP[3..0] to the appropriate level.

**Image Capture Mode***Continuous Capture Mode*

To operate in Continuous Capture Mode, set JMP0 to the LOW position. In this mode the board will continuously repeat the sequence of integrating and then reading out the CCD.

*Triggered Capture Mode*

To operate in Triggered Capture Mode, set JMP0 to the HIGH position. In this mode, the board requires an externally generated trigger signal to begin the single frame capture sequence. Upon receiving the trigger the board will Flush the CCD of accumulated charge, integrate, and then readout a single frame. Upon completion of readout, the board will wait for another trigger to repeat the sequence.

**Table 9. IMAGE CAPTURE MODES**

| JMP0 | Image Capture Mode      | Notes        |
|------|-------------------------|--------------|
| 0    | Continuous Capture Mode | Default Mode |
| 1    | Triggered Capture Mode  |              |

## BINNING MODE

To operate without pixel binning, set JMP1 to the LOW position. In this mode the CCD is operated to reset the CCD's floating diffusion after each pixel has been sampled off chip. To operate in 2 X 2 pixel binning mode, set JMP1

to the HIGH position. In this mode the CCD is operated to bin a 2 x 2 pixel charge packet in the CCD's floating diffusion before sampling and resetting the CCD's floating diffusion.

**Table 10. BINNING MODES**

| JMP1 | Binning Mode Operation | Notes        |
|------|------------------------|--------------|
| 0    | No Binning             | Default Mode |
| 1    | 2 X 2 Binning Mode     |              |

**Integration Timing Control Modes**

To operate in internally controlled integration mode, set JMP2 to the LOW position. When operating in internally controlled integration mode, the integration time is controlled by the INT MODE register and can be any one of the thirty-two different pre-defined integration times. Each of the pre-defined integration times is a multiple of the Unit integration time. (See Table 12) To operate in externally

controlled integration mode, set JMP2 to the HIGH position. When operating in externally controlled integration mode, the integration time is controlled by an external timer. An external input via the digital input interface, DIO15, is used to end the integration time. In this way any number of custom integration times can be created. The rising edge of the external input ends the integration time (See Figure 6).

**Table 11. INTEGRATION CONTROL MODES**

| JMP2 | Binning Mode Operation                  | Notes        |
|------|-----------------------------------------|--------------|
| 0    | Internally controlled Integration times | Default Mode |
| 1    | Externally controlled Integration times |              |

**Table 12. INTERNALLY SELECTABLE INTEGRATION TIMES**

| INT MODE Register Value | Integration Time (ms) | INT MODE Register Value | Integration Time (ms) |
|-------------------------|-----------------------|-------------------------|-----------------------|
| 0                       | 0                     | 16                      | 700                   |
| 1                       | 10                    | 17                      | 800                   |
| 2                       | 20                    | 18                      | 900                   |
| 3                       | 30                    | 19                      | 1000                  |
| 4                       | 40                    | 20                      | 2000                  |
| 5                       | 50                    | 21                      | 3000                  |
| 6                       | 60                    | 22                      | 4000                  |
| 7                       | 70                    | 23                      | 5000                  |
| 8                       | 80                    | 24                      | 6000                  |
| 9                       | 90                    | 25                      | 7000                  |
| 10                      | 100                   | 26                      | 8000                  |
| 11                      | 200                   | 27                      | 9000                  |
| 12                      | 300                   | 28                      | 10000                 |
| 13                      | 400                   | 29                      | 35000                 |
| 14                      | 500                   | 30                      | 50000                 |
| 15                      | 600                   | 31                      | 65000                 |

**Amplifier Disable Mode**

To operate without ever disabling the CCD output amplifier, set JMP3 to the LOW position.

To reduce the CCD output amplifier's VDD bias voltage during integration time, set JMP3 to the HIGH position. In

this mode, the CCD output amplifier supply (VDD) is switched to a lower voltage (ALT\_VDD) during integration, thereby disabling the amplifier and reducing power consumption. This feature may be used to reduce thermal artifacts in the image.

**Table 13. CCD AMPLIFIER OPERATING MODES**

| JMP3 | CCD Amplifier Operating Mode Control    | Notes        |
|------|-----------------------------------------|--------------|
| 0    | Internally controlled Integration times | Default Mode |
| 1    | Externally controlled Integration times |              |

## TIMING GENERATOR STATE MACHINE DESCRIPTION

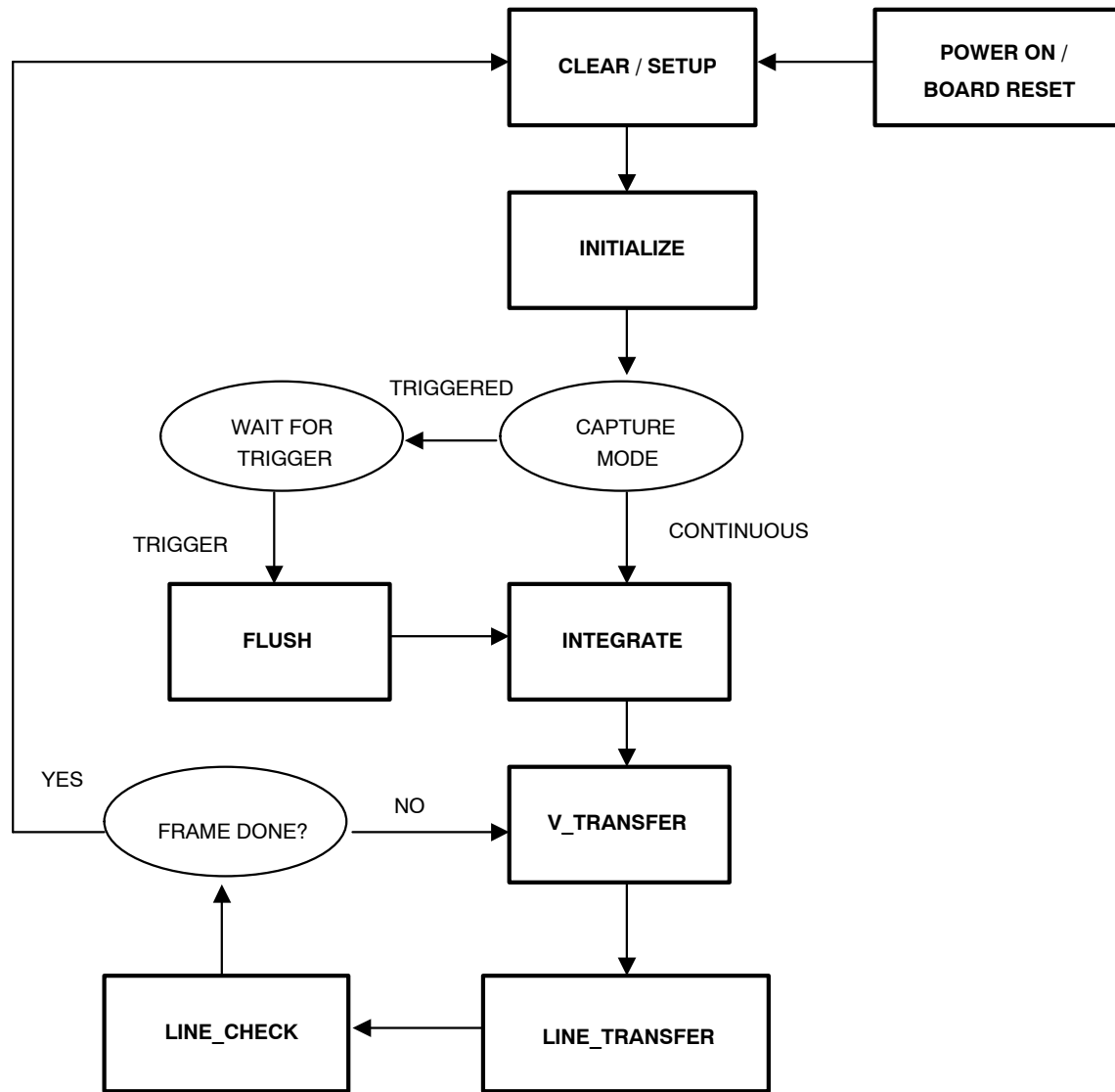


Figure 3. Timing Generator State Machine

**Power-On/Board Reset**

When the board is powered up or the Board Reset button is pressed, the Altera PLD is internally reset. When this occurs all internal counters are cleared, the state machine is reset, and all of the signal position and mode control registers are reset back to their default values. Upon completion of the board reset, the board will be ready to proceed according to the output mode selected.

**CLEAR/SETUP and INITIALIZE States**

The timing generator state machine is free running. It cycles through the states depending on the jumper settings and DIO inputs, and then returns back to the clear/setup state

to begin the next frame. The clear/setup state is used to reset the internal PLD counters at the beginning of each frame.

The INITIALIZE state is used to determine the selected operating modes, and to synchronize with the INTEGRATE\_CLK as needed.

In Continuous Capture mode, the state machine will wait in the INITIALIZE state for the next rising edge of INTEGRATE\_CLK (See Figure 5). The reason for the delay before entering the INTEGRATE state is so that state machine is synchronized with the INT\_CLK ensuring that consistent integration times are achieved when using the pre-defined internal integration modes.

### FLUSH State

The FLUSH state will occur in the Triggered Capture Mode only. During the FLUSH state, the CCD is flushed of any accumulated charge by running the vertical clocks

continuously for a number of lines. Upon flush completion, the state machine will wait in the flush state until the next rising edge of the INTEGRATE\_CLK.

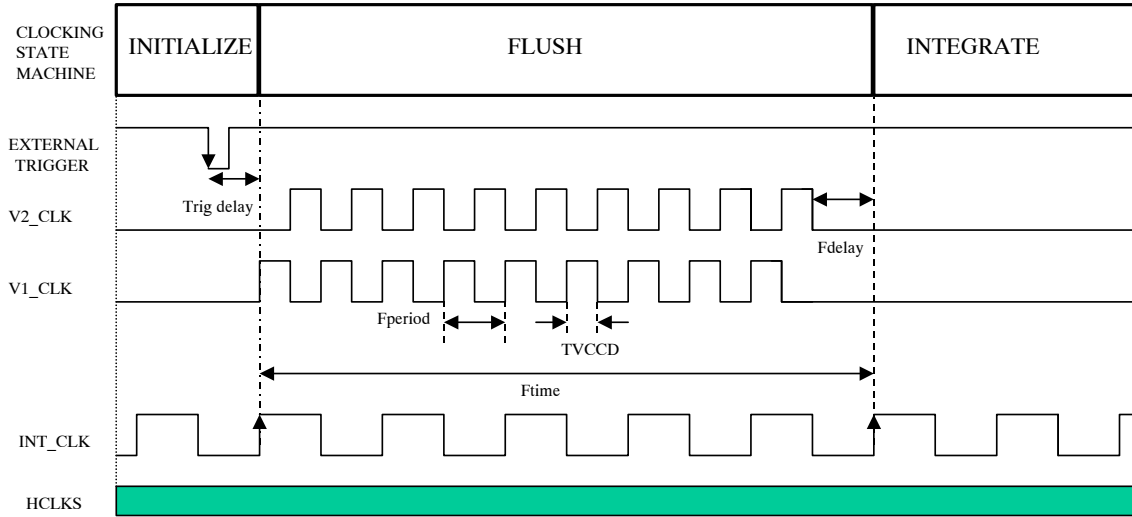


Figure 4. Flush Timing

### INTEGRATE State

During the INTEGRATE state, the output signal INTEGRATE goes high and stays high until the integration time is over. When the board is configured for internally controlled integration mode operation, the integration time

will depend on the value of the integration time register (See Table 12 and Figure 5). When the board is set up for externally controlled integration mode operation, the integration time will end when the external integration control signal (DIO15) is brought HIGH (See Figure 6).

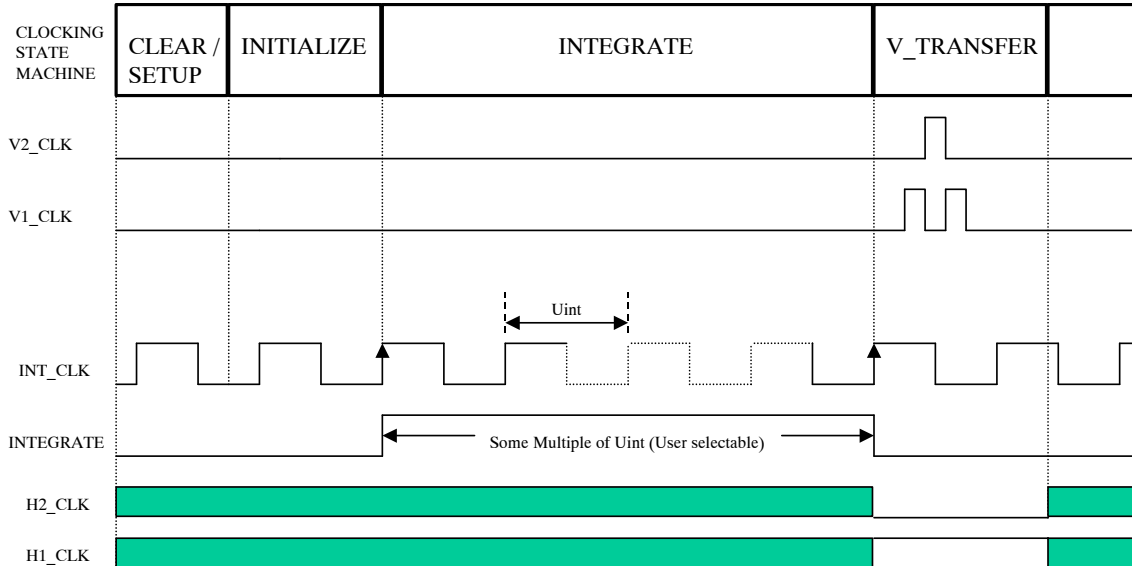


Figure 5. Integration Timing (Internal INT Mode)

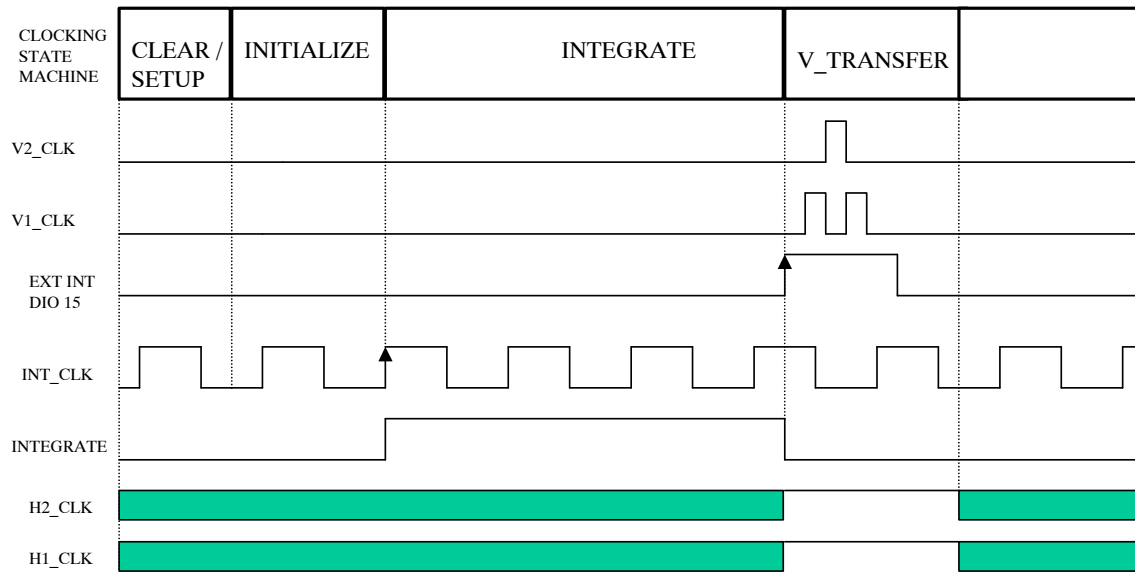


Figure 6. Integration Timing (External INT Mode)

#### V\_TRANSFER State

During the V\_TRANSFER state, each line (row) of charge is transported towards the horizontal CCD register using the Vertical clocks. A vertical transfer counter in the PLD is used to determine when the vertical clocks are forced high and low and when the vertical transfer time and horizontal delay time (Ths) are completed.

When operating in 2 X 2 Binning Mode, two lines of charge are transported towards the horizontal CCD register before the horizontal register is read out. The vertical clock timing is set in the timing generator PLD and is not adjustable.

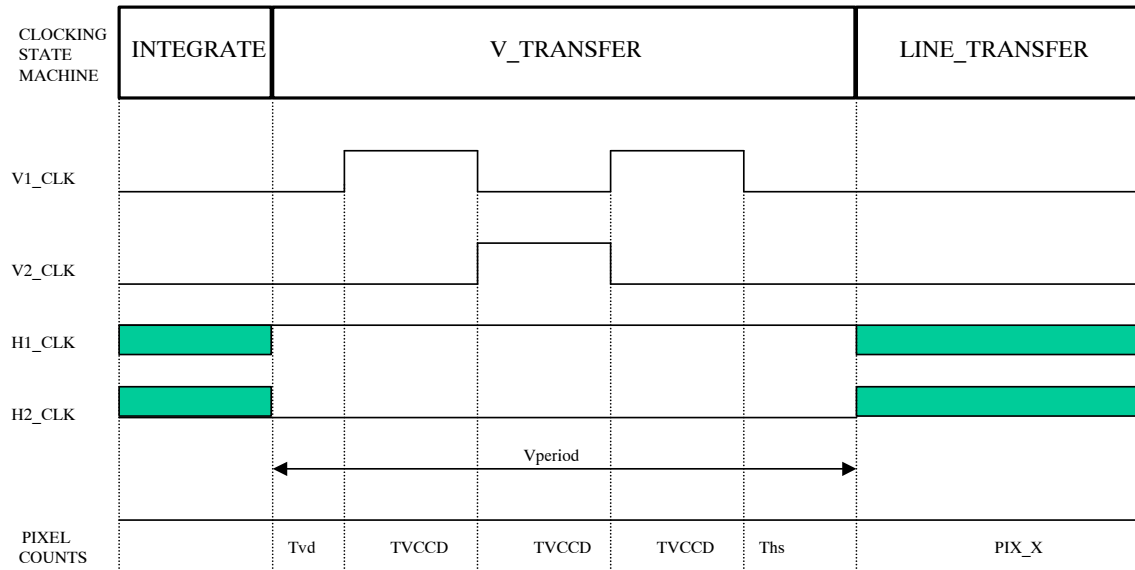


Figure 7. Vertical Transfer Timing

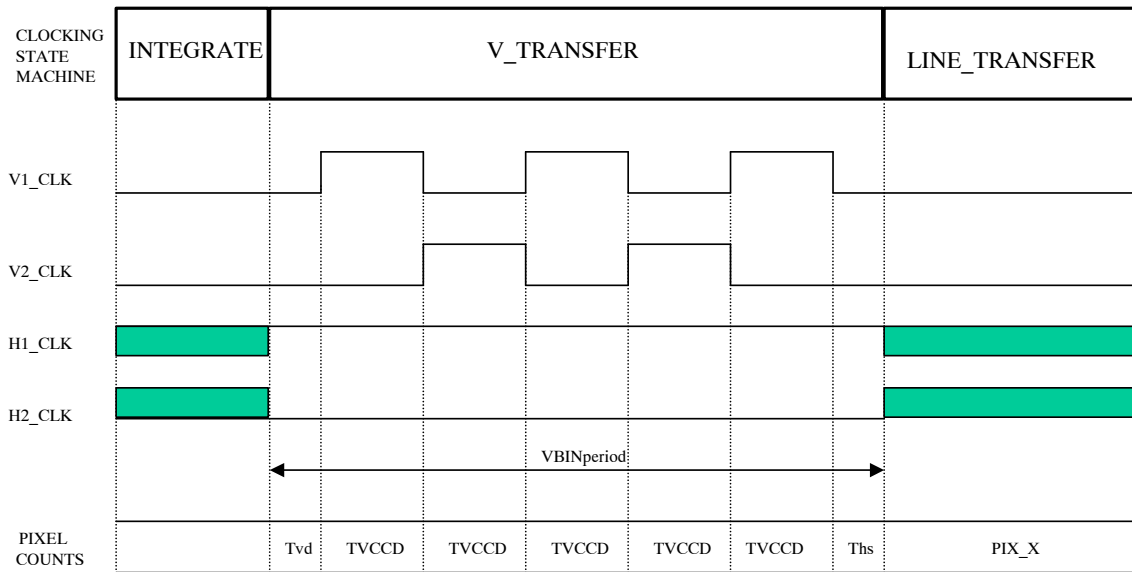


Figure 8. Vertical Transfer Timing (2 X 2 Binning)

#### LINE\_TRANSFER and LINE\_CHECK State

During the LINE\_TRANSFER state, charge is transported to the CCD output structure pixel by pixel. A line transfer counter in the PLD is used to keep track of how many pixels have been transported, and to synchronize the PCI-1424 framegrabber synchronization signals.

When operating in 2 X 2 Binning Mode, two pixels of charge are transported towards the output structure and the charge is allowed to accumulate on the floating diffusion before being sensed off-chip and the floating diffusion is

reset. In Binning Mode the RESET\_CCD clock, the CDS CLAMP and SAMPLE clocks, and the framegrabber PIX clock are all gated off every other pixel.

At the end of each line transfer, the Line counter is incremented in the LINE\_CHECK State. If all of the lines have been clocked out of the CCD, the state machine goes to the CLEAR/SETUP state; if not, the state machine returns to the V\_TRANSFER state, and transfers another line of charge into the horizontal register.

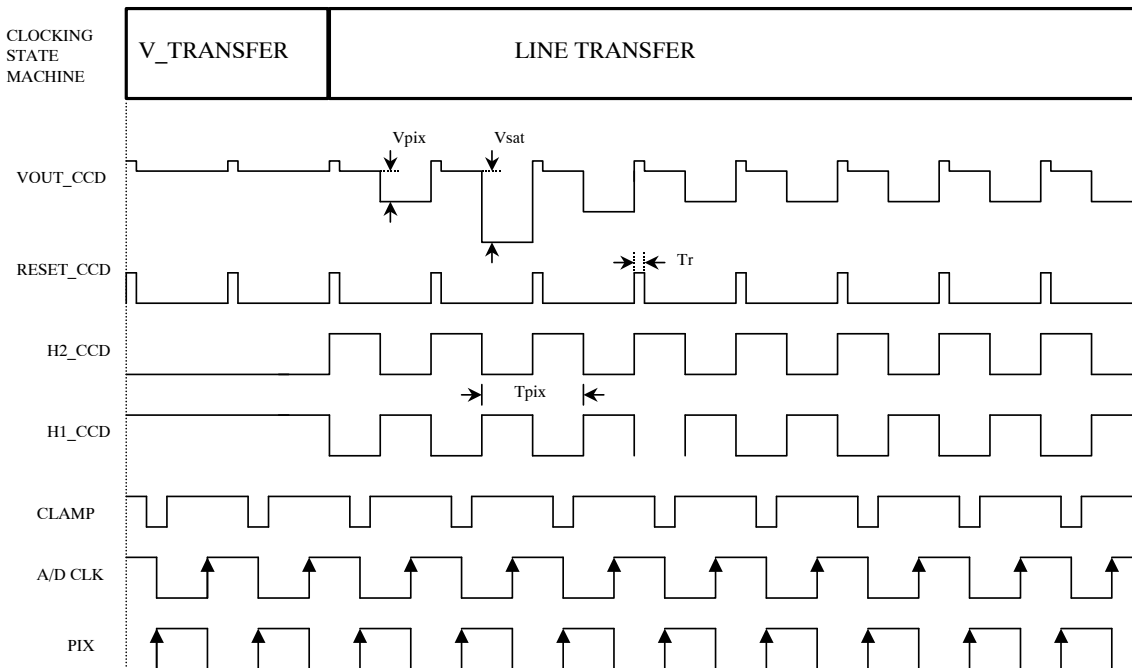


Figure 9. Horizontal Transfer Timing

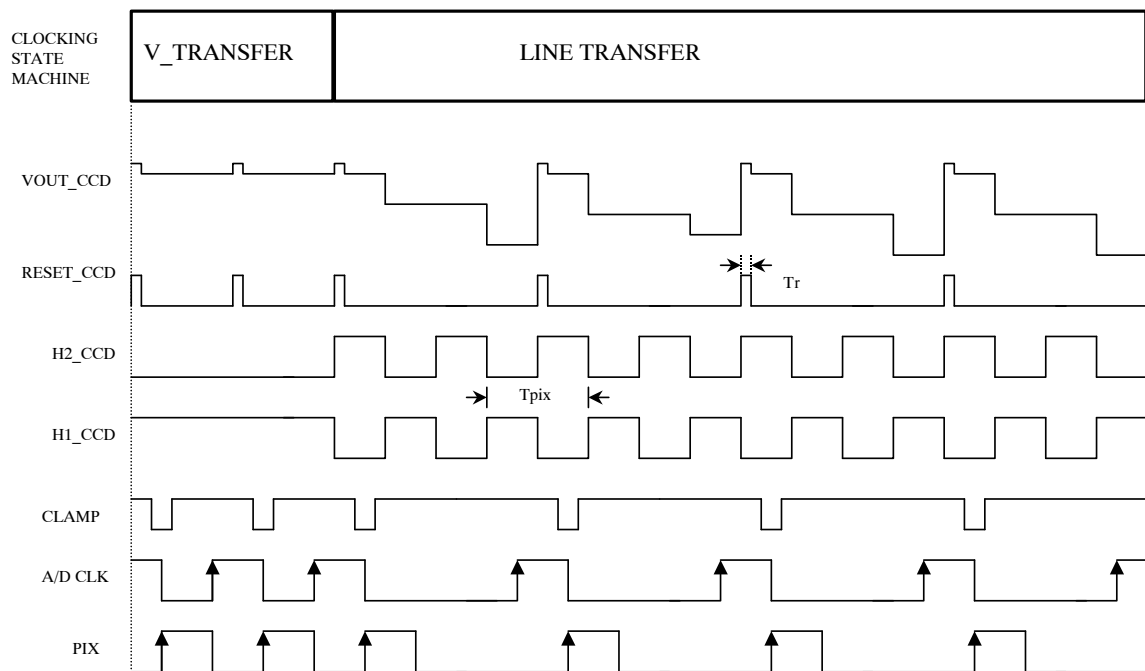


Figure 10. Horizontal Transfer Timing (2 X 2 Binning)

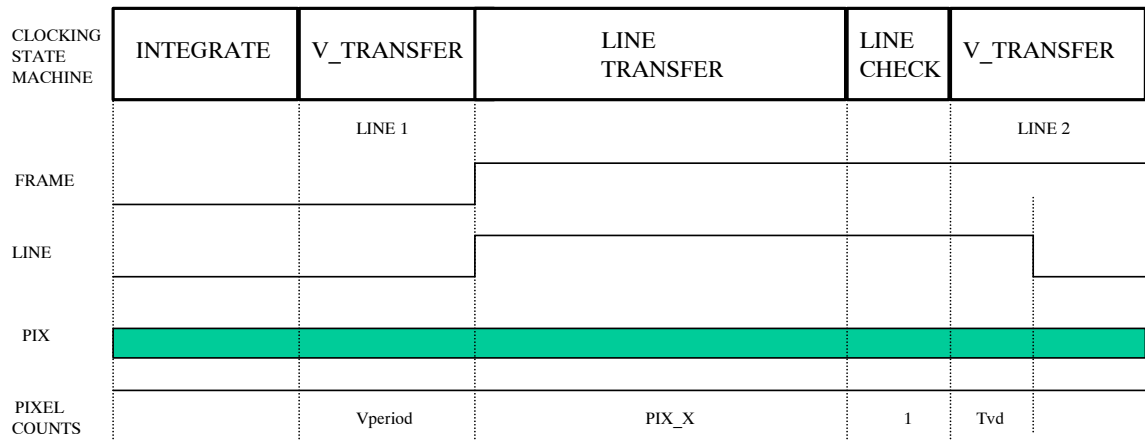


Figure 11. PCI-1424 Frame Grabber Timing

### Warnings and Advisories

When programming the Timing Board, the Imager Board must be disconnected from the Timing Board before power is applied. If the Imager Board is connected to the Timing Board during the reprogramming of the Altera PLD, damage to the Imager Board will occur.

Purchasers of a an Evaluation Board Kit may, at their discretion, make changes to the Timing Generator Board firmware. ON Semiconductor can only support firmware developed by, and supplied by, ON Semiconductor. Changes to the firmware are at the risk of the customer.

### Ordering Information

Please address all inquiries and purchase orders to:

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Phone: (585) 784-5500  
E-mail: [info@truesenseimaging.com](mailto:info@truesenseimaging.com)

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### References

- KAF-4320 Device Specification
- KAF-4320 Imager Board User Manual
- KAF-4320 Imager Board Schematic
- ADS-93X Timing Generator Board User Manual
- ADS-93X Timing Generator Board Schematic
- Datel ADS-933 Product Data Sheet

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