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# Profile sensors S15366 series

Contents



The S15366 series is a profile sensor with a center-of-gravity calculation circuit for detecting the incident position of the light spot. In the photosensitive area arranged two-dimensionally, the photosensitive area for the X-direction projection data is connected in one vertical column, and the photosensitive area for the Y-direction projection data is connected in one horizontal row using metal wiring. The sum of outputs of the photosensitive area is obtained for each line in the X and Y directions. Projection data can be obtained by collecting the data of all lines in order. Since the data size of the projection data is small, position detection and moving object detection can be performed faster than normal area image sensors. The center-of-gravity calculation circuit is built-in, so the center-of-gravity calculation result of light spot is output. It also supports a light spot automatic tracking mode.

## 1. SPI

### 1 - 1 Setting using SPI

Using an SPI (serial peripheral interface), it is possible to set sensor drive conditions and center-of-gravity calculation, and output center-of-gravity calculation results. Table 1-1 shows the SPI write/read terminals. The sensor readout settings and center-of-gravity calculation results made with SPI are output from the SPI_MISO terminal.

[Table 1-1] SPI write/read terminals

| Symbol | Description |
|---|---|
| SPI_MISO | SPI output signal |
| SPI_CS | SPI enable signal |
| SPI_SCLK | SPI clock signal |
| SPI_MOSI | SPI input signal |
| SPI_RSTB | SPI reset signal |

In external start pulse mode, integration time and blanking time are controlled by an external trigger signal (MST terminal). In center-of-gravity calculation mode, it is possible to set the number of pixels and pixel output threshold for center-of-gravity calculation. The following can be output as center-of-gravity calculation results.

- Center-of-gravity position coordinates
- Total pixel output value for center-of-gravity calculation
- Output value of the maximum output pixel
- Frame counter

### 1 - 2 Input/output timing of SPI

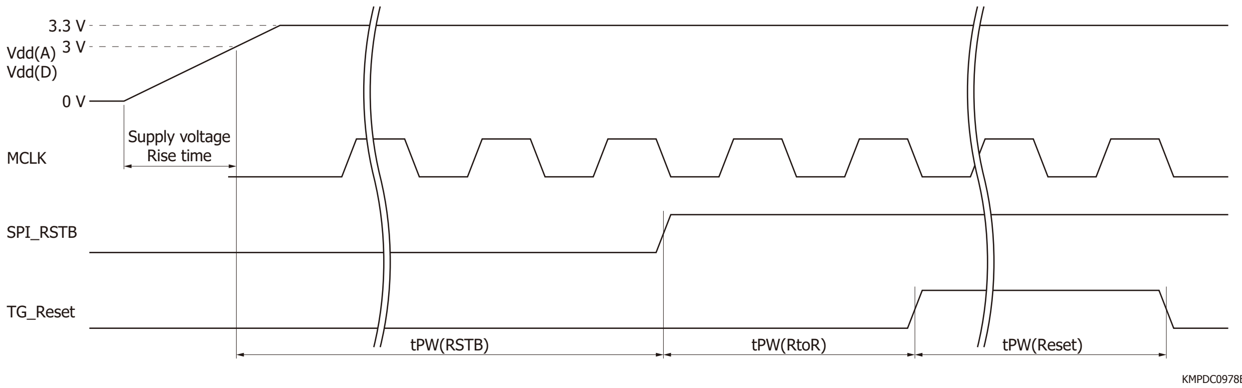
#### Reset input immediately after power-on

Once the analog/digital supply voltages have risen to the recommended operating conditions immediately after the power is turned on, input SPI_RSTB and TG_Reset at the timing shown in Figure 1-1, in order to initialize the timing generator and SPI register.

## [Table 1- 2] Setting using SPI and the like

| Parameter | Mode and explanation | |
|---|---|---|
| Frame start mode (Initial setting: internal start pulse mode) | Internal start pulse mode | Readout starts automatically when the power is turned on. The frame cycle is determined by the number of readout pixels and the blanking period. |
| | External start pulse mode | Readout starts when the rising edge of MST is detected. MST is also used to control the integration time. The low period of MST is roughly the integration time. |
| Integration time | Internal start pulse mode | Integration time is set using SPI. |
| | External start pulse mode | Integration time is set using MST. |
| Blanking period | Internal start pulse mode | Blanking period is set for 0 to 255 rows using SPI. |
| | External start pulse mode | Blanking period is from the end of a readout to the falling edge of the next Vsync. |
| Readout region | The readout region can be set at the pixel level. A single readout region can be set in each frame. | |
| Gain 1 | Select gain of the column circuit from 1x, 1.33x, 2x, and 4x.<br>Initial value: 1x | |
| Gain 2 | To avoid output saturation during binning, set gain to 1x to 0.063x, according to output.<br>Initial value: 1x | |
| Number of binning pixels | Select the number of binning pixels from 1, 2, 4, or 8 pixels.<br>Initial value: 1 pixel | |
| Voltage conversion range of the A/D converter | The lower voltage limit can be set between 0.8 to 1.55 V and the upper voltage limit between 1.85 to 2.6 V.<br>Initial value: lower voltage limit=1.0 V, upper voltage limit=2.25 V | |
| Standby mode | The SPI sets the standby mode to reduce current consumption. In standby mode, projection data and center-of-gravity calculation results cannot be acquired. | |
| Center-of-gravity calculation mode | Using SPI, the center-of-gravity position coordinates are calculated from the projection data for output. The center-of-gravity calculation result is not updated (projection data is output) when center-of-gravity calculation mode is off. | |
| Automatic tracking mode | Readout region centered on the maximum output pixel is set automatically. | |

## [Figure 1-1] Input timing of SPI_RSTB and TG_Reset




(Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, f(MCLK)=20 MHz max., at power-on)

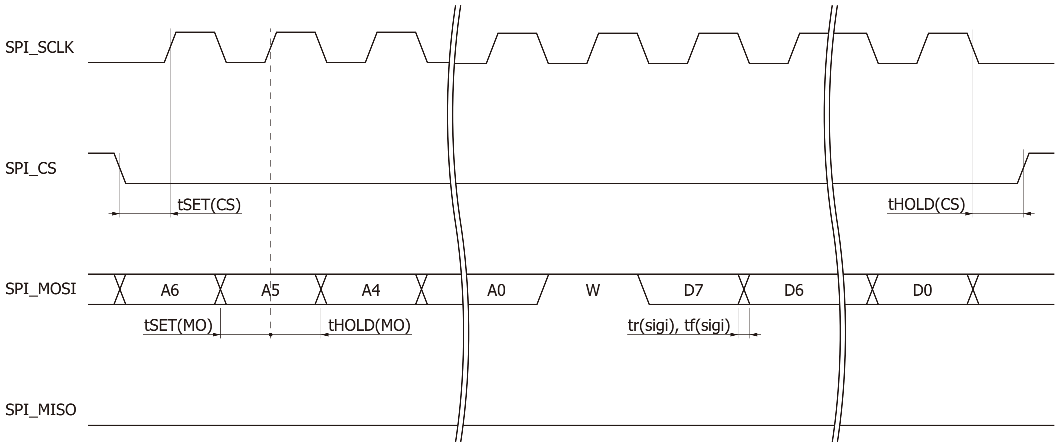
| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| SPI_RSTB signal low period | tPW(RSTB) | 100 | - | - | ns |
| Interval between SPI_RSTB and TG_Reset signals | tPW(RtoR) | 100 | - | - | ns |
| TG_Reset signal high period*1 *2 | tPW(Reset) | 12 | - | - | cycles |

*1: Correct data cannot be obtained in the frame immediately after input of the TG_Reset signal. Please use data from the second frame onward.
*2: “1 cycle” is one cycle of the master clock pulse.

## SPI input

Figure 1-2 shows the SPI input timing.

[Figure 1-2] SPI input timing



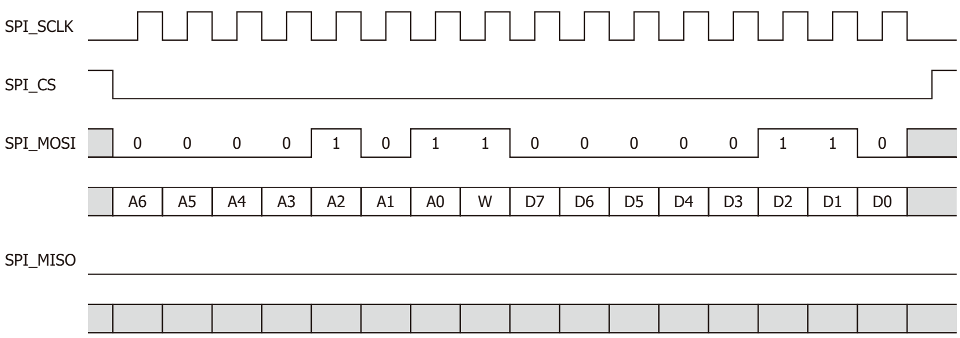

KMPDC0979EA

(Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, f(MCLK)=20 MHz max.)

| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| SPI clock pulse frequency | f(SCLK) | - | - | 20 | MHz |
| SPI setting time (SPI_CS) | tSET(CS) | 7 | - | - | ns |
| SPI hold time (SPI_CS) | tHOLD(CS) | 7 | - | - | ns |
| SPI setting time (SPI_MOSI) | tSET(MO) | 7 | - | - | ns |
| SPI hold time (SPI_MOSI) | tHOLD(MO) | 7 | - | - | ns |
| Digital input signal's rise time*3 | tr(sigi) | - | 5 | 7 | ns |
| Digital input signal's fall time*3 | tf(sigi) | - | 5 | 7 | ns |

*3: Time for the input voltage to rise or fall between 10% and 90%

[Figure 1-3] Input example when writing 0x06 to address 0x05

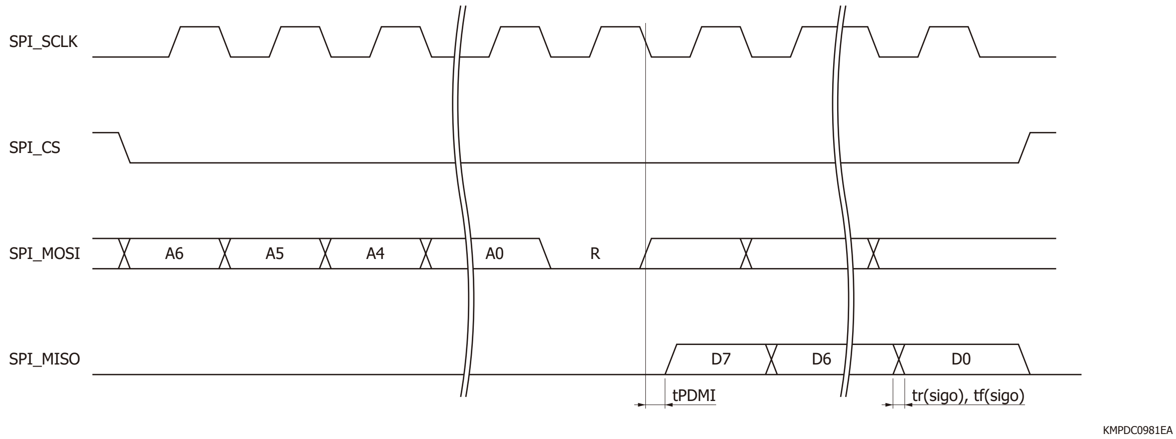



KMPDC0980EA

## SPI output

Figure 1-4 shows the SPI output timing.

[Figure 1-4] SPI output timing

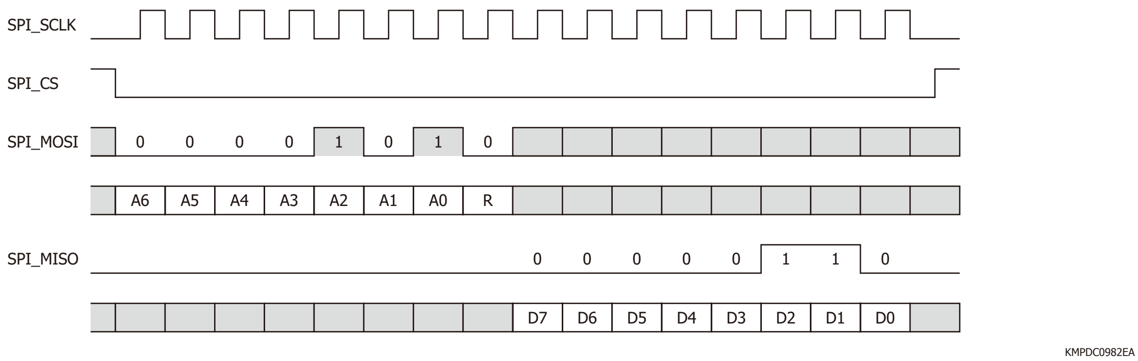



(Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, f(MCLK)=20 MHz max.)

| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| SPI_SCLK - SPI_MISO output delay time*4 | tPDMI | - | - | 25 | ns |
| Digital output signal's rise time*4 | tr(sigo) | - | 10 | 12 | ns |
| Digital output signal's fall time*4 | tf(sigo) | - | 10 | 12 | ns |

*4: Time for the output voltage to rise or fall between 10% and 90% when there is a 10 pF load capacitor is attached to the output terminal

[Figure 1-5] Input example when reading out address 0x05




## Timing when SPI setting is reflected

If sensor drive conditions and center-of-gravity calculation circuit settings are made by the time of SPI update, they will be reflected at the timing shown in Table 1-3. The center-of-gravity calculation result is updated at the timing of "CoG result update" in the next frame [Figure 3-2 (P.13), Figure 3-3 (P.14)].
Note: CoG: center of gravity

[Table 1-3] Timing when sensor drive conditions and center-of-gravity calculation circuit settings are reflected

| SPI setting parameters | Timing to be reflected |
|---|---|
| Mode, Blanking, WinSY, WinSX, WinW, ADC, Gain, Calc_area, Max_th | Next frame of "SPI update" |
| Integ | Frame after next frame of "SPI update" |

# 1 - 3 SPI register

When SPI_RSTB is set to low, all parameters will be the initial values. SPI can be set 100 ns after the rising edge of SPI_RSTB. Fix SPI_RSTB to high for a period of 100 ns before and after SPI update. Table 1-4 shows the SPI register map

[Table 1-4] SPI register map

(a) S15366-256

| Address | Name | Access | Initial value | | Description |
|---|---|---|---|---|---|
| | | | Binary | Decimal | |
| 0 | Mode | R/W | 0000 0111 | 7 | Mode[0]: switching the trigger mode<br>1: internal start pulse mode<br>0: external start pulse mode<br>Mode[1]: switching on/off the center-of-gravity calculation function<br>1: on, 0: off<br>Mode[2]: standby mode<br>1: off, 0: on*5<br>Mode[3]: automatic tracking mode<br>1: on, 0: off<br>(Do not change other bits) |
| 1 | Integ_U | R/W | 1111 1111 | 255 | Integration time in internal start pulse mode |
| 2 | Integ_L | R/W | 1111 1111 | 255 | |
| 3 | Blanking | R/W | 0000 0000 | 0 | Wait time between frames in internal start pulse mode |
| 4 | WinSY | R/W | 0000 0000 | 0 | Y-direction readout start pixel position |
| 5 | WinSX | R/W | 0000 0000 | 0 | X-direction readout start pixel position |
| 6 | WinW | R/W | 1111 1111 | 255 | Readout pixels |
| 7 | ADC | R/W | 1000 0100 | 132 | Voltage range of the A/D converter<br>ADC[7:4]: upper voltage limit (VRT)<br>ADC[3:0]: lower voltage limit (VRB) |
| 8 | Gain | R/W | 1100 0000 | 192 | Gain, binning value<br>Gain[7:6]: switching the charge amplifier feedback capacitance (gain 1)<br>Gain[5:2]: readout circuit gain adjustment (gain 2)<br>Gain[1:0]: switching the number of binning pixels |
| 9 | Not used (Please do not read or write) | | | | |
| 10 | Calc_area | R/W | 0000 0000 | 0 | Number of pixels for the center-of-gravity calculation<br>Calc_area[1:0]=0: 5 pixels<br>Calc_area[1:0]=1: 9 pixels<br>Calc_area[1:0]=2: 19 pixels<br>Calc_area[1:0]=3: 29 pixels<br>(Do not change other bits) |
| 11 | Max_th | R/W | 0000 0000 | 0 | Output threshold for the center-of-gravity calculation |
| 12 | Frame_cnt | R | - - - - 0000 | 0 | Frame counter |
| 13 | Maxpos_X_int | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the X-direction (integer part) |
| 14 | Maxpos_X_dec | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the X-direction (decimal part) |
| 15 | Not used (Please do not read or write) | | | | |
| 16 | Maxpos_Y_int | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the Y-direction (integer part) |
| 17 | Maxpos_Y_dec | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the Y-direction (decimal part) |
| 18 | Not used (Please do not read or write) | | | | |
| 19 | Out_XY_sum_U | R | 0000 0000 | 0 | Total output for center-of-gravity calculation |
| 20 | Out_XY_sum_L | R | 0000 0000 | 0 | |
| 21 | Maxval_X | R | 0000 0000 | 0 | Maximum output in the X-direction |
| 22 | Maxval_Y | R | 0000 0000 | 0 | Maximum output in the Y-direction |

*5: To turn it from on to off, it is necessary to send the command (0x07) twice, then enter TG_Reset.

### (b) S15366-512

| Address | Name | Access | Initial value | | Description |
|---|---|---|---|---|---|
| | | | Binary | Decimal | |
| 0 | Mode | R/W | 0000 0111 | 7 | Mode[0]: switching the trigger mode<br>1: internal start pulse mode<br>0: external start pulse mode<br>Mode[1]: switching on/off the center-of-gravity calculation function<br>1: on, 0: off<br>Mode[2]: standby mode<br>1: off, 0: on*5<br>Mode[3]: switching on/off the automatic tracking mode<br>1: on, 0: off<br>(Do not change other bits) |
| 1 | Integ_U | R/W | 1111 1111 | 255 | Integration time in internal start pulse mode |
| 2 | Integ_L | R/W | 1111 1111 | 255 | |
| 3 | Blanking | R/W | 0000 0000 | 0 | Wait time between frames in internal start pulse mode |
| 4 | WinSY_U | R/W | ---- ---0 | 0 | Y-direction readout start pixel position<br>Set "-" to 0. |
| 5 | WinSY_L | R/W | 0000 0000 | 0 | |
| 6 | WinSX_U | R/W | ---- ---0 | 0 | X-direction readout start pixel position<br>Set "-" to 0. |
| 7 | WinSX_L | R/W | 0000 0000 | 0 | |
| 8 | WinW_U | R/W | ---- ---1 | 1 | Readout pixels<br>Set "-" to 0. |
| 9 | WinW_L | R/W | 1111 1111 | 255 | |
| 10 | ADC | R/W | 1000 0100 | 132 | Voltage range of the A/D converter<br>ADC[7:4]: upper voltage limit (VRT)<br>ADC[3:0]: lower voltage limit (VRB) |
| 11 | Gain | R/W | 1100 0000 | 192 | Gain, binning value<br>Gain[7:6]: switching the charge amplifier feedback capacitance (gain 1)<br>Gain[5:2]: readout circuit gain adjustment (gain 2)<br>Gain[1:0]: switching the number of binning pixels |
| 12 | Not used (Please do not change the settings) | | | | |
| 13 | Calc_area | R/W | 0000 0000 | 0 | Number of pixels for the center-of-gravity calculation<br>Calc_area[1:0]=0: 5 pixels<br>Calc_area[1:0]=1: 9 pixels<br>Calc_area[1:0]=2: 19 pixels<br>Calc_area[1:0]=3: 29 pixels<br>(Do not change other bits) |
| 14 | Max_th | R/W | 0000 0000 | 0 | Output threshold for the center-of-gravity calculation |
| 15 | Frame_cnt | R | ---- 0000 | 0 | Frame counter |
| 16 | Maxpos_X_int_U | R | ---- ---0 | 0 | Center-of-gravity position coordinates in the X-direction (integer part) |
| 17 | Maxpos_X_int_L | R | 0000 0000 | 0 | |
| 18 | Maxpos_X_dec | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the X-direction (decimal part) |
| 19 | Not used (Please do not change the settings) | | | | |
| 20 | Maxpos_Y_int_U | R | ---- ---0 | 0 | Center-of-gravity position coordinates in the Y-direction (integer part) |
| 21 | Maxpos_Y_int_L | R | 0000 0000 | 0 | |
| 22 | Maxpos_Y_dec | R | 0000 0000 | 0 | Center-of-gravity position coordinates in the Y-direction (decimal part) |
| 23 | Not used (Please do not change the settings) | | | | |
| 24 | Out_XY_sum_U | R | 0000 0000 | 0 | Total output for center-of-gravity calculation |
| 25 | Out_XY_sum_L | R | 0000 0000 | 0 | |
| 26 | Maxval_X | R | 0000 0000 | 0 | Maximum output in the X-direction |
| 27 | Maxval_Y | R | 0000 0000 | 0 | Maximum output in the Y-direction |

*5: To turn it from on to off, it is necessary to send the command (0x07) twice, then enter TG_reset.

Note: WinSY, WinSX, WinW, Maxpos_X_int, and Maxpos_Y_int of this document
S15366-256: WinSY[7:0], WinSX[7:0], WinW[7:0], Maxpos_X_int[7:0], Maxpos_Y_int[7:0]
S15366-512: WinSY[8:0], WinSX[8:0], WinW[8:0], Maxpos_X_int[8:0], Maxpos_Y_int[8:0]

## 1 - 4 Sensor drive conditions

### Readout mode

(1) Internal start pulse mode

When Mode[0] is set to 1 (the initial setting), it will change the mode to internal start pulse mode. In internal start pulse mode, the frame starts automatically once the power supply is turned on. No external trigger is necessary in this mode. The frame cycle is determined by the number of readout pixels and the blanking period.

(2) External start pulse mode

When Mode[0] is set to 0, it will change the mode to external start pulse mode. In external start pulse mode, the frame starts at the rising edge of the MST. Also, integration time is controlled by MST (see Figure 1-6, "1-4 Sensor drive conditions | Integration time").

### Center-of-gravity calculation function

When Mode[1] is set to 1 (the initial setting), the center-of-gravity calculation function will turn on, and when it is set to 0, that function will turn off. In the off state, the center-of-gravity calculation result will not be updated.

### Standby mode

When Mode[2] is set to 0, standby mode will turn on, and when it is set to 1, standby mode will turn off [when turning it from on to off, it is necessary to send the command (0x07) twice, then input TG_reset]. Start TG_Reset and hold for at least 12 MCLK, then turn it down. For current consumption in standby mode, see the "Profile sensor S15366 series" datasheet (P.4).

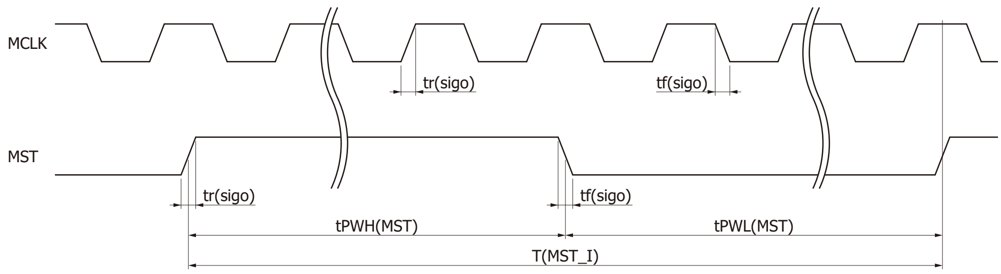
### Automatic tracking mode

When Mode[3] is set to 1, it will change the mode to automatic tracking mode. When automatic tracking mode and partial readout are used together, it is possible to detect the incident position of the light spot easily, at high speed. When doing partial readout without using automatic tracking mode, set the readout start pixel position with WinSX and WinSY, and set the number of readout pixels with WinW (see "1-4 Sensor drive conditions | Partial readout region") When automatic tracking mode and partial readout are used together, the maximum output pixel is detected in the previous frame, and the readout start pixel is automatically set so that the pixel is in the center of the readout region. If the maximum output pixel is near the edge of the photosensitive area, the center of the readout region shifts to the inside of the photosensitive area (the number of readout pixels stays at the set value). This setting is made for each frame, and the readout region changes by automatically tracking the incident position of the light spot. Readout start pixel position is given by equation (1-1).

Readout start pixel position
= int {Maximum output pixel position of previous frame
- (Number of readout pixels - 1)/2}·········(1-1)
Note: int: integer

Set the number of readout pixels with WinW. If the maximum output pixel is detected at the edge of the readout region, it will be determined that the incident position of the light spot is outside the readout area. In the next frame, all pixels will be readout and the pixel position of maximum output will be detected again.

[Figure 1-6] MCLK, MST input timing



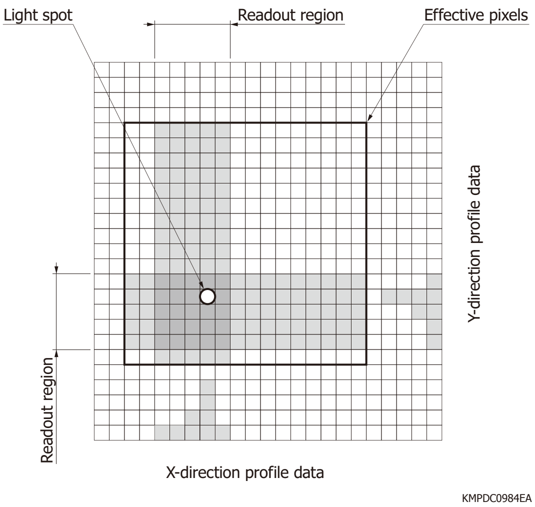

(Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, f(MCLK)=20 MHz max.)

| Parameter | Symbol | S15366-256 | | | S15366-512 | | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Master start pulse interval*6 *7 | T(MST_I) | 6336 | - | - | 12480 | - | - | cycles |
| Master start pulse width*6 | tPWH(MST) | 84 | - | - | 84 | - | - | cycles |
| | tPWL(MST) | 84 | - | - | 84 | - | - | cycles |

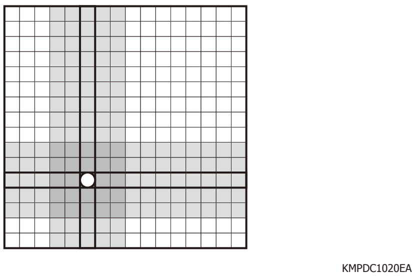
*6: It needs to be set to T(MST_I) = tPWH(MST) + tPWL(MST). Master start pulse input is only required in external start pulse mode [Figure 3-3 (P.14)].
*7: When doing readout of N pixels, it takes {(N + 5) × 2 + 6} × 12 cycles.

[Figure 1-7] Operation schematic of automatic tracking mode

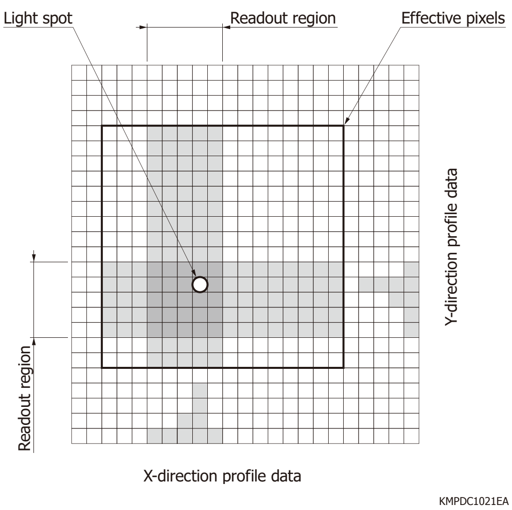
(a) Output from the nth frame




(b) Readout region setting for (n + 1) th frame




(c) Output from (n + 1) th frame




## Integration time

(1) Internal start pulse mode

Integration time of internal start pulse mode is set with Integ[15:0]. When Integ[15:0] increases by 1, integration time increases by 12 cycles of the master clock pulses (readout time for 1 pixel). Integration time is given by equation (1-2).

Integration time = (Integ[15:0] + 7) × 12/f(MCLK) [s]·········(1-2)

We have used global shutter readout in this product, so integration time starts and ends simultaneously for all pixels. The end of integration time is after one cycle of the master clock pulse from the rising edge of Vsync [Figure 3-2 (P.13)].

(2) External start pulse mode

Integration time in external start pulse mode is determined by the low period of the MST. Integration starts between the falling edge of MST and the falling edge after 78 to 90 master clock pulse cycles, and integration ends between the rising edge of MST and the falling edge after 78 to 90 master clock pulse cycles [Figure 3-3 (P.14)]. Integration time is given by equation (1-3).

The CLK obtained by dividing MCLK by 12 inside the sensor is generated. The start and end of integration are controlled with a signal synchronized with this CLK. For this reason, the start/end timing of integration has a range of "after 78 to 90 master clock pulse cycles."

Timing when integration starts = int {(L9 + 6)/12} × 12 + 84.5
Timing when integration ends = int {(L9 + tPWL(MST) + 6)/12} × 12 + 84.5
Integration time
= {int {(L9 + tPWL(MST) + 6)/12} - int {(L9 + 6)/12}} × 12/f(MCLK) [s]·········(1-3)

## Blanking period

(1) Internal start pulse mode

Set the blanking period of internal start pulse mode with Blanking[7:0]. The initial value of Blanking[7:0] is 0. Frame cycle is given by equation (1-4).

Frame cycle
= {(2 + Blanking) × (WinW + 6) + 6} × 12/f(MCLK) [s]·········(1-4)

To make integration time longer than the pixel readout period, set an appropriate blanking period.

(2) External start pulse mode

The blanking period for external start pulse mode is determined by MST. The blanking period lasts from the end of readout to the next falling edge of Vsync [Figure 3-3].

Settings described below to P.10 are common to internal start pulse mode and external start pulse mode.

## Partial readout region

Set the partial readout region with WinSY, WinSX, and WinW at the pixel level. Only 1 readout region can be set for each frame.

(1) WinSY

Set the readout start pixel in the Y-direction with WinSY [readout starts from (WinSY + 1)th pixel]. The initial setting is WinSY=0.

(2) WinSX

Set the readout start pixel in the X-direction with WinSX [readout starts from (WinSX + 1)th pixel]. The initial setting is WinSX=0.

(3) WinW

Set the number of readout pixels with WinW (the number of readout pixels is WinW + 1 in both the X and Y-directions). The initial setting is WinW=255 (S15366-256), 511 (S15366-512).

Be careful to keep WinSY + WinW or WinSX + WinW from exceeding the number of effective pixels [256 (S15366-256), 512 (S15366-512)]. If the number of effective pixels is exceeded, dummy data will be output.

## A/D conversion voltage range

Set the conversion voltage range of the A/D converter with ADC[7:0]. The initial setting is ADC[7:0]=132 (ADC[7:4]=8, ADC[3:0]=4). Table 1-5 shows the relationship between ADC[7:0] and the upper voltage limit and lower voltage limit of the A/D converter.

[Table 1-5] ADC[7:0] vs A/D converter upper voltage limit (VRT), lower voltage limit (VRB)

| ADC[7:4] | VRT (V) | ADC[3:0] | VRB (V) |
|---|---|---|---|
| 0 | 1.85 | 0 | 0.8 |
| 1 | 1.9 | 1 | 0.85 |
| 2 | 1.95 | 2 | 0.9 |
| 3 | 2 | 3 | 0.95 |
| 4 | 2.05 | 4 | 1 |
| 5 | 2.1 | 5 | 1.05 |
| 6 | 2.15 | 6 | 1.1 |
| 7 | 2.2 | 7 | 1.15 |
| 8 | 2.25 | 8 | 1.2 |
| 9 | 2.3 | 9 | 1.25 |
| 10 | 2.35 | 10 | 1.3 |
| 11 | 2.4 | 11 | 1.35 |
| 12 | 2.45 | 12 | 1.4 |
| 13 | 2.5 | 13 | 1.45 |
| 14 | 2.55 | 14 | 1.5 |
| 15 | 2.6 | 15 | 1.55 |

## Gain

Adjust the feedback capacitance of the charge amplifier with Gain[7:6]. Gain is proportional to the reciprocal of the feedback capacitance of the charge amplifier. Table 1-6 shows the relationship between Gain[7:6] and gain.

[Table 1-6] Gain[7:6] vs. Gain1

| Decimal | Binary | | Charge amplifier feedback capacitance (pF) | Note |
|---|---|---|---|---|
| | Gain[7] | Gain[6] | | |
| 0 | 0 | 0 | 0.2 | |
| 1 | 0 | 1 | 0.4 | |
| 2 | 1 | 0 | 0.6 | |
| 3 | 1 | 1 | 0.8 | Initial setting |

Set the gain of the readout circuit with Gain[5:2]. Table 1-7 shows the relationship between Gain[5:2] and gain.

[Table 1-7] Gain[5:2] vs. gain 2

| Decimal | Binary | | | | Gain | Note |
|---|---|---|---|---|---|---|
| | Gain[5] | Gain[4] | Gain[3] | Gain[2] | | |
| 0 | 0 | 0 | 0 | 0 | 1.000 | Initial setting |
| 1 | 0 | 0 | 0 | 1 | 0.500 | |
| 2 | 0 | 0 | 1 | 0 | 0.333 | |
| 3 | 0 | 0 | 1 | 1 | 0.250 | |
| 4 | 0 | 1 | 0 | 0 | 0.200 | |
| 5 | 0 | 1 | 0 | 1 | 0.167 | |
| 6 | 0 | 1 | 1 | 0 | 0.143 | |
| 7 | 0 | 1 | 1 | 1 | 0.125 | |
| 8 | 1 | 0 | 0 | 0 | 0.111 | |
| 9 | 1 | 0 | 0 | 1 | 0.100 | |
| 10 | 1 | 0 | 1 | 0 | 0.091 | |
| 11 | 1 | 0 | 1 | 1 | 0.083 | |
| 12 | 1 | 1 | 0 | 0 | 0.077 | |
| 13 | 1 | 1 | 0 | 1 | 0.071 | |
| 14 | 1 | 1 | 1 | 0 | 0.067 | |
| 15 | 1 | 1 | 1 | 1 | 0.063 | |

### Binning

Set the number of binning pixels with Gain[1:0]. Table 1-8 shows the relationship between Gain[1:0] and the number of binning pixels. Sensitivity increases in proportion to the number of binning pixels. When binning and partial readout are set, readout in the X-direction starts from "WinSX + 1"th pixel, and readout in the Y-direction starts from "WinSY + 1"th pixel. Be careful to keep (number of binning pixels × WinW) + (WinSX or WinSY) from exceeding the number of effective pixels [256 (S15366-256), 512 (S15366-512)]. If the number of effective pixels is exceeded, dummy data will be output.

[Table1-8] Gain[1:0] vs. number of binning pixels

| Decimal | Binary | | Number of binning pixels | Note |
|---|---|---|---|---|
| | Gain[1] | Gain[0] | | |
| 0 | 0 | 0 | 1 | Initial setting |
| 1 | 0 | 1 | 2 | |
| 2 | 1 | 0 | 4 | |
| 3 | 1 | 1 | 8 | |

# 2. Center-of-gravity calculation

## 2 - 1 Center-of-gravity calculation setting

### Number of pixels

Set the number of pixels used by the center-of-gravity calculation circuit for center-of-gravity calculation with Calc_area[1:0] [Table 2-1]. The center-of-gravity calculation circuit does center-of-gravity calculation using the output data of the number of pixels set in Calc_area[1:0], centered on the maximum output pixels in the X and Y directions respectively. For example, if the settings are Calc_area[1]=1 and Calc_area[0]=0, and the output from the 100th pixel on the X-axis is maximum, then the 91st to 109th pixels (19 pixels) are used for center-of-gravity calculation. However, if the light spot is at the edge of the photosensitive area and there are (number of pixels for center-of-gravity calculation - 1)/2 pixels or fewer from the maximum output pixel to the outermost effective pixel, then calculation cannot be done correctly. For example, if the number of pixels for center-of-gravity calculation is set to 19, and the maximum output pixel is in the 1st to 9th pixels, or the 248th to 256th pixels (S15366-256) or 504th to 512th pixels (S15366-512), then calculation cannot be done correctly.
The pixels for center-of-gravity calculation should be larger than the diameter of the light spot. We recommend setting the number of pixels as few as possible to reduce the effect of background light.

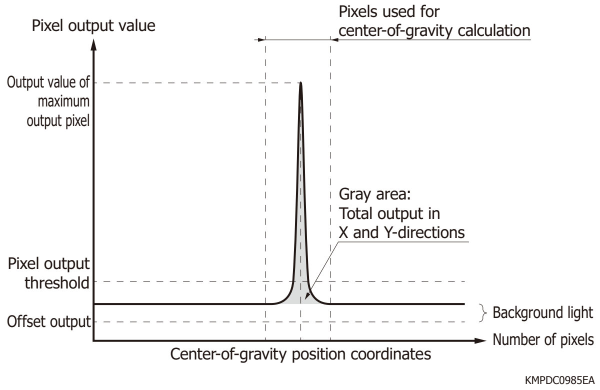
[Table 2-1] Calc_area[1:0] vs. number of pixels used for center-of-gravity calculation

| Decimal | Binary | | Number of pixels for center-of-gravity calculation | Note |
|---|---|---|---|---|
| | Calc_area [1] | Calc_area [0] | | |
| 1 | 0 | 0 | 5 | Initial setting |
| 2 | 0 | 1 | 9 | |
| 3 | 1 | 0 | 19 | |
| 4 | 1 | 1 | 29 | |

### Pixel output threshold

Set the threshold of pixel output (8-bit digital value) used for center-of-gravity calculation with Max_th [7:0]. The center-of-gravity calculation circuit ignores outputs that are smaller than the pixel output threshold.
The pixel output threshold should be sufficiently smaller than the output of the pixels illuminated by the light spot. We recommend setting the pixel output threshold to be larger than the light output from background light [Figure 2-1].

[Figure 2-1] Pixel output threshold, total output




## 2 - 2 Center-of-gravity calculation result

The center-of-gravity position coordinates, total output of the pixels for the center-of-gravity calculation, output of the maximum output pixel, and frame counter are obtained as results of center-of-gravity calculation. If the outputs of multiple pixels are the same, then center-of-gravity calculation is done centered on the pixel with the smallest pixel no.

### Center-of-gravity position coordinates

The center-of-gravity position coordinates are the values obtained by subtracting 1 from the pixel no. illuminated by the light spot. The center-of-gravity position coordinates are saved to Maxpos_X_int and Maxpos_X_dec[7:0] for the X-direction and to Maxpos_Y_int and Maxpos_Y_dec[7:0] for the Y-direction. Center-of-gravity coordinates are fixed points. Maxpos_X_int and Maxpos_Y_int are 8-bit (S15366-256) or 9-bit (S15366-512) integers, while Maxpos_X_dec[7:0] and Maxpos_Y_dec[7:0] are 8-bit decimals. When the index mark is set to the bottom left, the left coordinate is 0 in the X-direction and the bottom coordinate is 0 in the Y-direction.

### Total output of pixels for center-of-gravity calculation

The total output of pixels for center-of-gravity calculation in the X and Y directions are saved to Out_xy_sum[15:0] (see “2-1 Center-of-gravity calculation settings | Number of pixels”).

### Output of the maximum output pixel

The output of the maximum output pixel is saved to Maxval_X[7:0] and Maxval_Y[7:0] in the X and Y directions, respectively. If the light level is large and the pixel output has reached saturation, the accuracy of the center-of-gravity calculation result may decrease. Light level and gain need to be adjusted to prevent saturation.

### Frame counter

Frame counter is saved to Frame_cnt[3:0]. The frame counter is increased in increments of 1 for each frame. By acquiring the frame counter along with the center-of-gravity calculation results, it is possible to check that the center-of-gravity calculation result is acquired for each frame. The frame counter repeats from 0 to 15. By setting SPI_RSTB to low, the frame counter can be set to its initial value of 0.

### Center-of-gravity calculation method

First, the position of the maximum output pixel is detected from the profile obtained with the 1st frame. By obtaining the 0th and 1st moments from the pixel output in the center-of-gravity calculation range centered on that position, it calculates the center-of-gravity position. The center-of-gravity calculation result is saved to the register. The procedure for center-of-gravity calculation is shown below.

[Table 2-2] Parameters for center-of-gravity calculation

| Parameter | Symbol | Value |
|---|---|---|
| Pixel no. | n | 0 to 255 |
| Pixel output | Dn | 0 to 255 |
| Smoothed pixel output | Dn' | 0 to 255 |
| Partial readout start pixel no. | WinSX, WinSY | 0 to 255 |
| Number of partial readout pixels | WinW | 0 to 255 |
| Center-of-gravity calculation range | Calc_area[1:0] | [00]=5, [01]=9,<br>[10]=19, [11]=29 |
| Pixel output threshold | Max_th | 0 to 255 |

①Output ($D_{n-1}$, Dn, $D_{n+1}$) for every 3 pixels (n - 1, n, n + 1) are smoothed for all pixels in the center-of-gravity calculation range [equation (2-1)].

$$D'n = \frac{D_{n-1} + 2Dn + D_{n+1}}{4} \quad \cdots\cdots\cdots(2\text{-}1)$$

Dn′: output after smoothing
n : pixel no. (WinS* + 1 to WinS* + WinW - 1)
WinS*: WinSX (horizontal direction) or WinSY (vertical direction)

②The position (nmax) is detected for the pixel (the maximum output pixel) with the maximum output D'n after smoothing. The maximum output pixel (pixel no. n) must meet all of conditions A to D shown below.

A: Greater than the output of pixel no. (n - 1) and greater than or equal to the output of pixel no. (n + 1)
$D'_{n-1} < D'n \geq D'_{n+1}$ ·········(2-2)

B: Output at or above the maximum pixel threshold
$D'n \geq Max\_th$ ·········(2-3)

C: Output greater than the previous maximum output pixel

D: n is within the range of equation (2-4).
$WinS^* + (Calc\_area - 1)/2 + 1 \leq n \leq WinS^* + WinW - (Calc\_area - 1)/2 - 1$ ·········(2-4)

③Set the center-of-gravity calculation range (Calc_area) centered on the maximum output pixel (detected in step ②). The outputs of [nmax - (Calc_area - 1)/2 - 1] pixels and [nmax + (Calc_area - 1)/2 + 1] pixels on both edges 1 pixel outside of the center-of-gravity calculation range are compared. The larger value is made the offset and subtracted from each pixel output in the center-of-gravity calculation range to find the sum (0th moment) of all pixels of that value (using the pixel outputs before smoothing and the offset value).

④First, 0 is set as the position (nmax) of the maximum output pixel of the value obtained by subtracting the offset from each pixel output in the center-of-gravity calculation range. Next, weights of -1 and +1 are placed on the positions of the pixels at both edges and -2 and +2 on the positions of the pixels on the outside. Finally, the sum of those values is set as the 1st moment (using the pixel outputs before smoothing and offset value).

⑤The center-of-gravity position is calculated from the position (nmax) of the maximum output pixel, the 0th moment, and the 1st moment.

$$\text{Center-of-gravity position} = \text{nmax} + \frac{\text{1st moment}}{\text{0th moment}} \quad \cdots\cdots\cdots (2\text{-}5)$$

⑥The center-of-gravity position is converted to absolute value coordinates (integer: 8-bit, decimal: 8-bit) using the number of binning pixels and the partial readout start position.

# 3. Timing chart

## 3 - 1 Digital output signal timing

The output signals of frame data consist of frame data signal Dout[7:0], synchronization signals Vsync and Hsync, and PCLK [Figure 3-1].

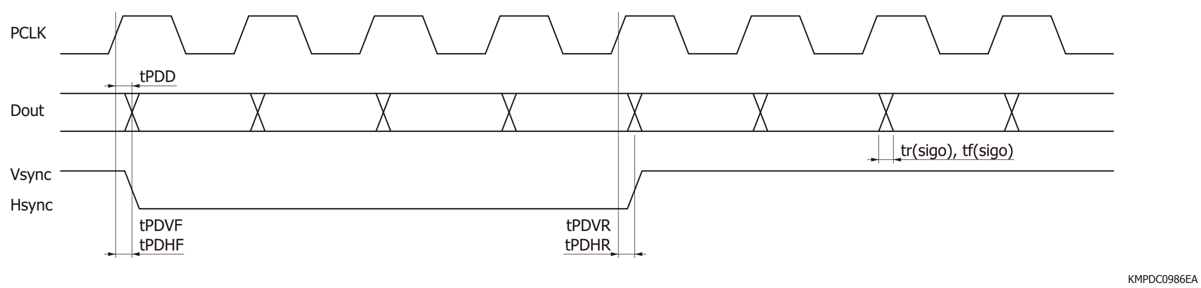
## 3 - 2 Timing chart of internal start pulse mode

The timing chart of the internal start pulse mode is shown in Figure 3-2. "SPI update" is the timing for updating to the setting written in the SPI register, "CoG result update" is the timing for updating to the center-of-gravity calculation result, and "End of integration" is the timing when integration time ends.

## 3 - 3 Timing chart of external start pulse mode

The timing chart of the external start pulse mode is shown in Figure 3-3. "Start of integration" is the timing when integration time starts.

[Figure 3-1] Digital output signal timing



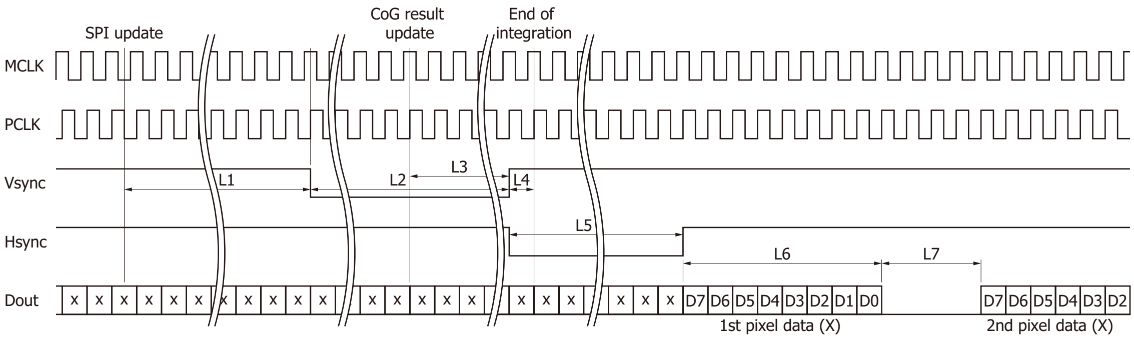

(Ta=25 °C, Vdd(A)=Vdd(D)=3.3 V, f(MCLK)=20 MHz max.)

| Parameter | | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Video data rate | | VR | f(MCLK)/12 | | | Hz |
| Digital output voltage | High | Vsigo(H) | Vdd(D) - 0.25 | Vdd(D) | - | V |
| | Low | Vsigo(L) | - | 0 | 0.25 | V |
| Digital output signal's rise time*8 *9 | | tr(sigo) | - | 10 | 12 | ns |
| Digital output signal's fall time*8 *9 | | tf(sigo) | - | 10 | 12 | ns |
| Delay between video output sync signal and video output | | tPDD | - | - | 7 | ns |
| Delay between video output sync signal and X/Y-direction sync signal | Rise time | tPDHR | - | - | 7 | ns |
| | Fall time | tPDHF | - | - | 7 | ns |
| Delay between video output sync signal and frame sync signal | Rise time | tPDVR | - | - | 7 | ns |
| | Fall time | tPDVF | - | - | 7 | ns |

*8: Dout, SPI_MISO, Vsync, Hsync, PCLK
*9: Time for output voltage to rise or fall between 10% and 90% with a 10 pF capacitor connected to the output terminal

## [Figure 3-2] Timing chart of internal start pulse mode

### (a) At start time of frame data output




Note: x of Dout: period during which dummy data is output

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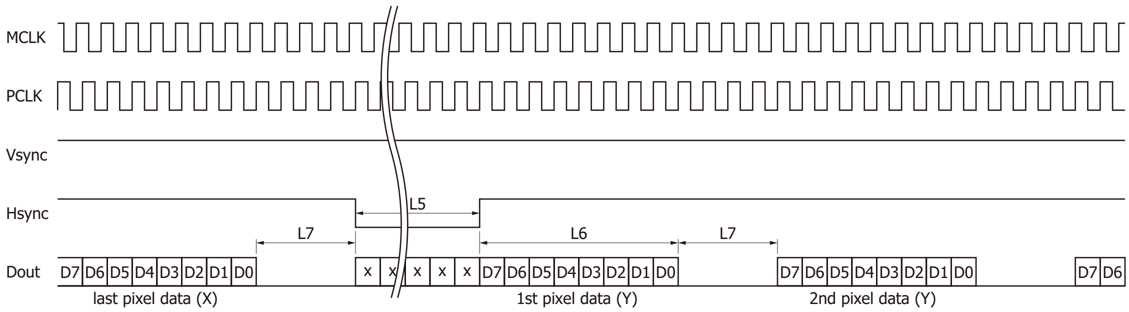
### (b) Period from the end of X-direction data output until the start of Y-direction data output

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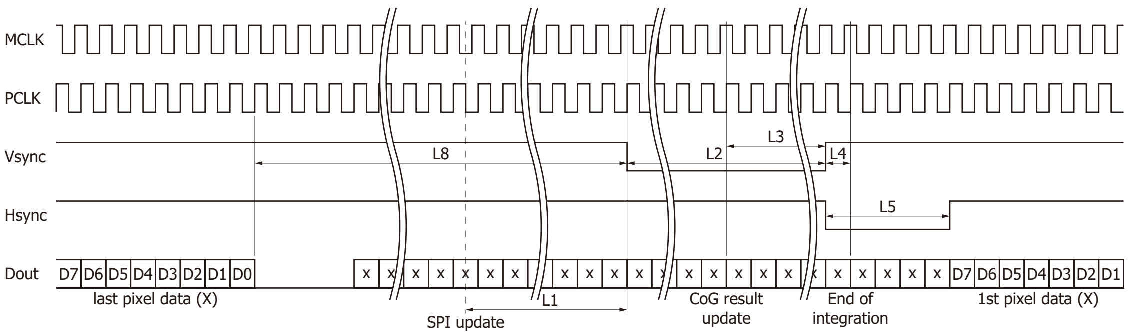
### (c) Period from the end of Y-direction data output until the start of X-direction data output of the next frame




Note: x of Dout: period during which dummy data is output

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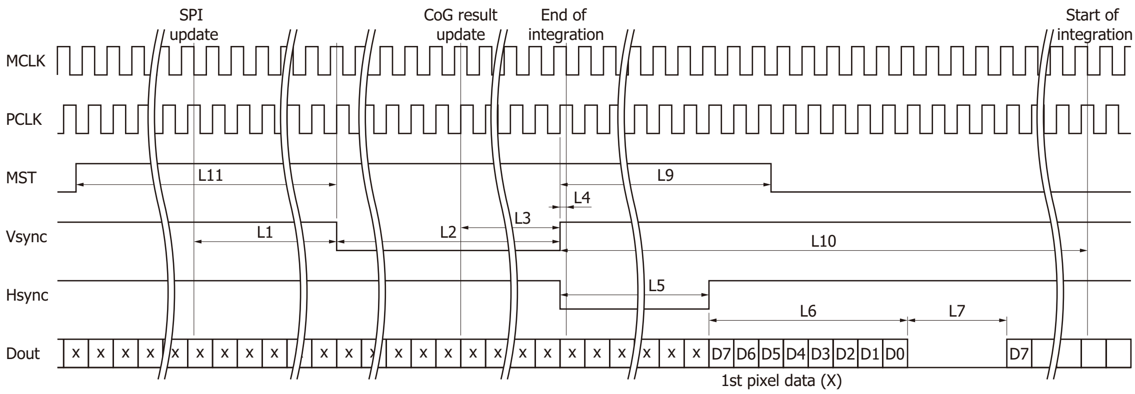
| Parameter | PCLK pulses (cycles) | Description |
|---|---|---|
| L1 | 23.5 | Period from SPI register update timing to Vsync falling edge |
| L2 | 36 | Vsync low period |
| L3 | 10 | Period from center-of-gravity calculation result update timing to Vsync rising edge |
| L4 | Less than 1 | Period from Vsync rising edge to the end of integration |
| L5 | 60 | Hsync low period |
| L6 | 8 | "Dout" output period for one pixel |
| L7 | 4 | Dout blanking period |
| L8*10 | (6 + WinW) × Blanking × 12 + 40 | Period from the timing when Dout ends to the falling edge of Vsync |

*10: Refer to "1-4 Sensor drive conditions | Integration time."

## [Figure 3-3] Timing chart of external start pulse mode

### (a) At start time of frame data output

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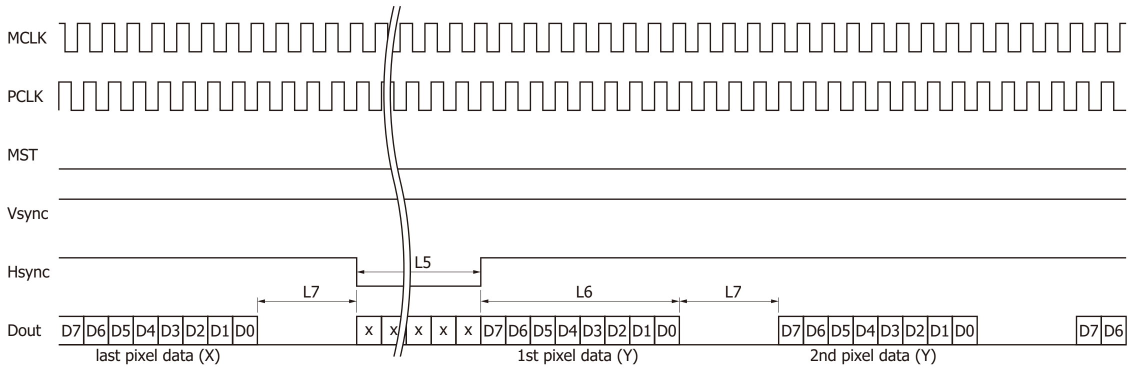
### (b) Period from the end of X-direction data output until the start of Y-direction data output

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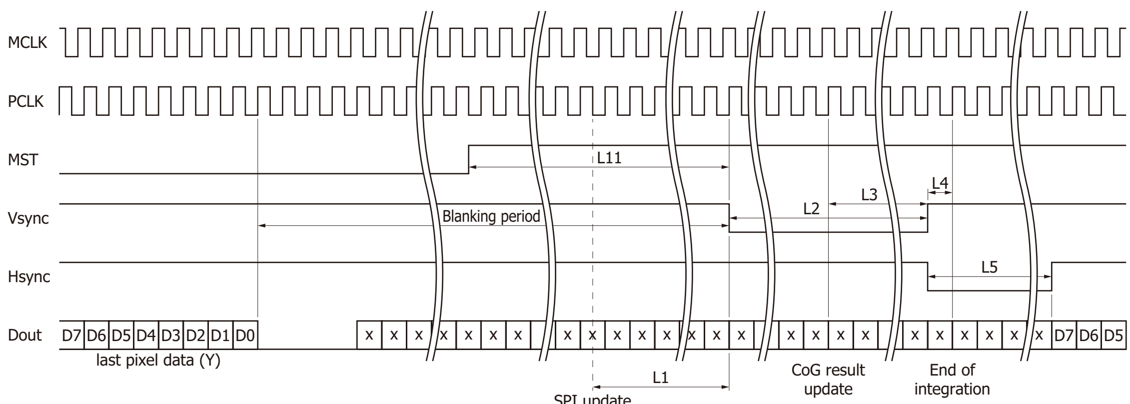
### (c) Period from the end of Y-direction data output until the start of X-direction data output of the next frame




Note: x of Dout: period during which dummy data is output

KMPDC0992EA

| Parameter | PCLK pulses (cycles) | Description |
|---|---|---|
| L1 | 23.5 | Period from SPI register update timing to Vsync falling edge |
| L2 | 36 | Vsync low period |
| L3 | 10 | Period from center-of-gravity calculation result update timing to Vsync rising edge |
| L4 | Less than 1 | Period from Vsync rising edge to the end of integration |
| L5 | 60 | Hsync low period |
| L6 | 8 | “Dout” output period for one pixel |
| L7 | 4 | Dout blanking period |
| L9 | Arbitrary value determined by MST setting value | Period from Vsync rising edge to MST falling edge |
| L10*11 | { int( L9 + 6 )/12) } × 12 + 84.5 | Period from Vsync rising edge to the start of integration |
| L11*11 | 42 to 54 | Period from MST rising edge to Vsync falling edge |

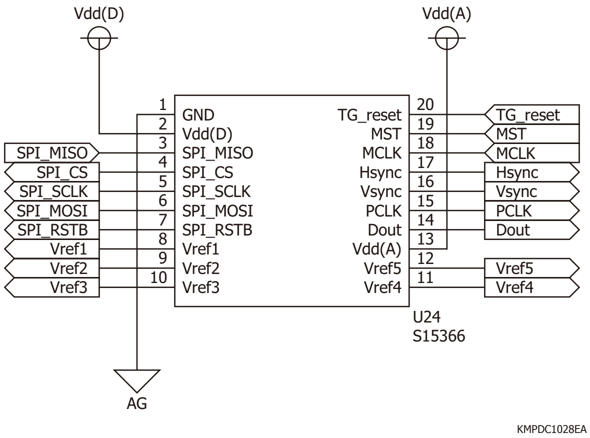
*11: Refer to “1-4 Sensor drive conditions | Integration time.”

# 4. Connection circuits

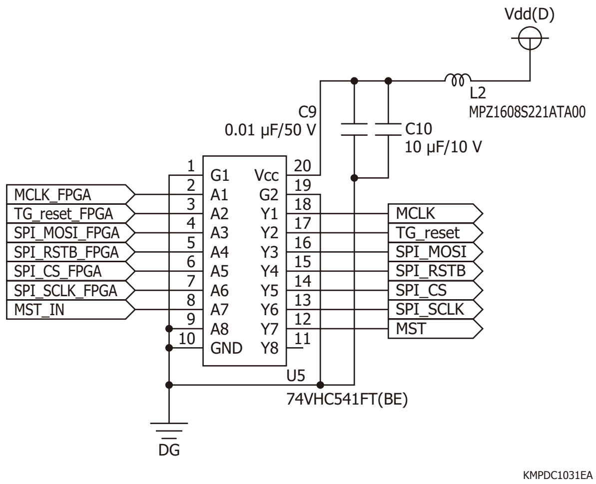
Figure 4-1 shows examples of connection circuits. Input or output signals to the digital terminals via digital buffers. Also, attach capacitors to supply voltage terminals and bias voltage terminals. For the S15366-512, connect all 16 sub-pads to ground.

[Figure 4-1] Connection circuit examples

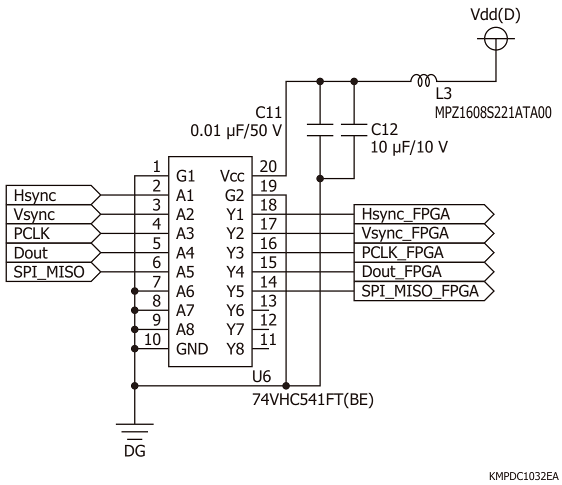
(a) S15366 series



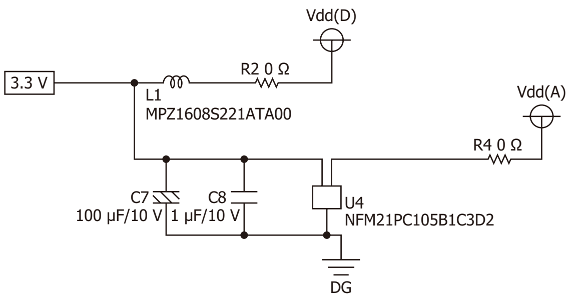

(b) Digital buffer
[For input to S15366 series]




[For output from S15366 series]



## (c) Power supply peripheral circuit

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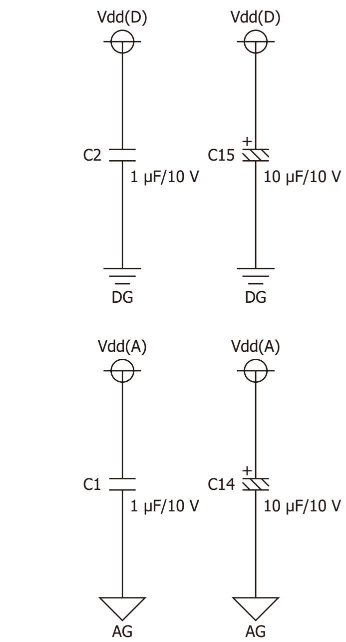
## (d) Bypass capacitor for power supply

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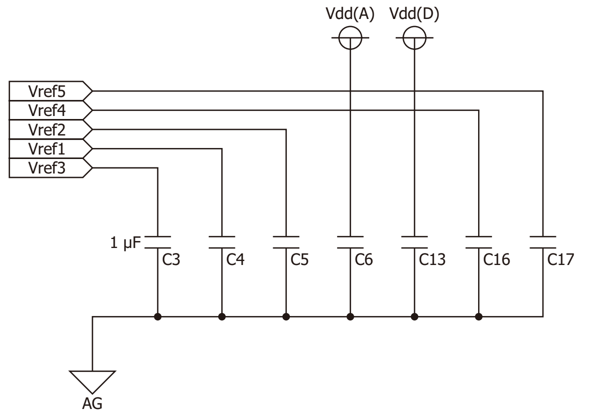
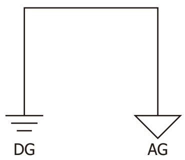
## (e) Bypass capacitor for Vref




KMPDC1029EA

## (f) Ground




KMPDC1027EA

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Product specifications are subject to change without prior notice due to improvements or other reasons. This document has been carefully prepared and the information contained is believed to be accurate. In rare cases, however, there may be inaccuracies such as text errors. Before using these products, always contact us for the delivery specification sheet to check the latest specifications.
The product warranty is valid for one year after delivery and is limited to product repair or replacement for defects discovered and reported to us within that one year period. However, even if within the warranty period we accept absolutely no liability for any loss caused by natural disasters or improper product use.



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