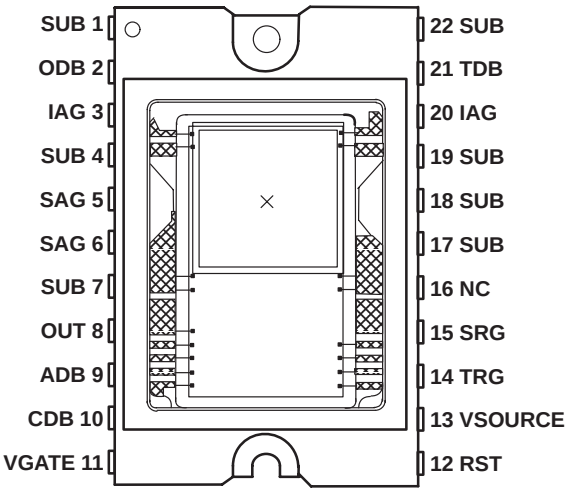
- **High-Resolution, Solid-State Frame-Transfer Image Sensor**
- **11.3-mm Image Area Diagonal**
- **1000 (H) x 1000 (V) Active Elements**
- **Up to 30 Frames per Second**
- **8-μm Square Pixels**
- **Low Dark Current**
- **Advanced Lateral-Overflow-Drain Antiblooming**
- **Single Pulse Image Area Clear Capability**
- **Dynamic Range . . . More than 60 dB**
- **High Sensitivity and Quantum Efficiency**
- **Nondestructive Charge Detection Through Texas Instruments (TI™) Advanced BCD Node Technology**
- **High Near-IR and Blue Response**
- **Solid-State Reliability With No Image Burn-In, Residual Imaging, Image Distortion, Image Lag, or Microphonics**



description

The TC281 is a frame-transfer charge-coupled-device (CCD) image sensor that provides a very high-resolution image acquisition capability for image-processing applications such as robotic vision, medical X-ray analysis, and metrology. The image sensing area measures 8 mm horizontally and 8 mm vertically; the image-area diagonal measures 11,3 mm and the sensor has 8-μm square pixels. The image area contains 1000 active lines with 1000 active pixels per line. The dark reference signal can be obtained from ten dark reference lines located between the image area and the storage area, 28 dark reference pixels located at the left edge of each horizontal line, and 8 dark reference pixels located at the right edge of each horizontal line.

The storage section of the TC281 contains 1010 lines with 1036 pixels per line. The area is protected from exposure to light by a metal layer. Photoelectric charge that is generated in the image area of the sensor can be transferred into the storage section in less than 110 μs. After the image capture is completed (integration time), the image readout is accomplished by transferring charge, one line at a time, into the serial register located below the storage area. The serial register contains 1036 active pixels and 9 dummy pixels. The maximum serial-register data rate is 40 megapixels per second. If the storage area needs to be cleared of all charge, charge may be quickly transferred across the serial registers into the clearing drain located below the register.

A high performance bulk charge detection (BCD) structure converts charge from each pixel into an output voltage. A low-noise, two-stage, source-follower amplifier further buffers the signal before it is sent to the output pin. A readout rate of 30 frames per second is easily achievable with this device.

The blooming-protection of the sensor is based on an advanced lateral-overflow-drain structure (ALOD). The antiblooming function is activated when a suitable dc bias is applied to the overflow-drain pin. With this type of blooming protection it is also possible to clear the image area of charge completely. This is accomplished by providing a single 10V pulse of at least 1 μs duration to the overflow-drain pin.

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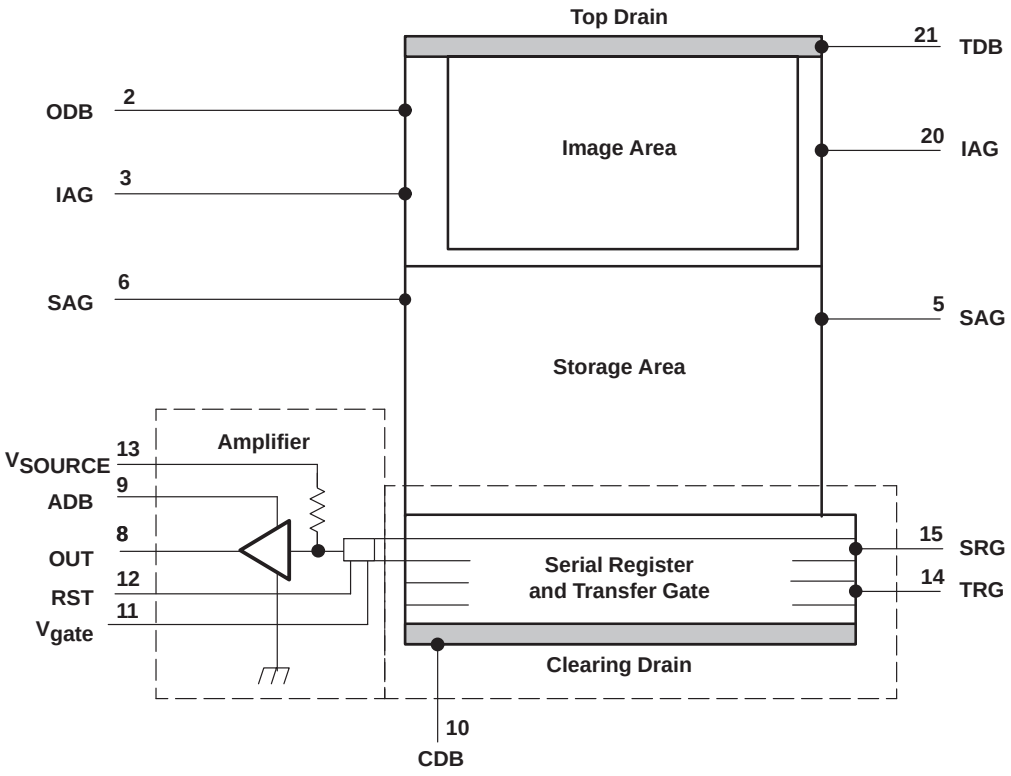
description (continued)

The TC281 uses TI-proprietary advanced virtual-phase (AVP) technology, the advanced lateral-overflow-drain structure, and the BCD detection node. These features provide the TI image sensing devices with a high blue response, high near-IR sensitivity, low dark current, high photoresponse uniformity, and a single-phase clocking. The TC281 is characterized for operation from -10°C to 45°C.

functional block diagram



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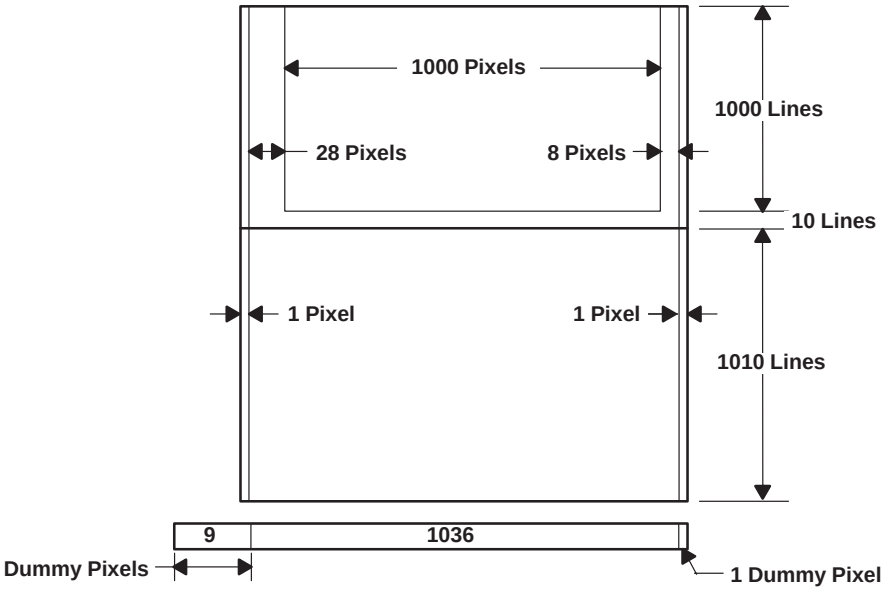
sensor topology diagram



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
ADB	9	I	Supply voltage for amplifier-drain bias
CDB	10	I	Supply voltage for clearing-drain bias
IAG	3, 20	I	Image area gate
NC	16		No connect
ODB	2	I	Supply voltage overflow-drain antiblooming bias
OUT	8	O	Output signal
RST	12	I	Reset gate
SAG	5, 6	I	Storage area gate
SRG	15	I	Serial register gate 1
SUB	1, 4, 7, 17, 18, 19, 22		Substrate and clock return
TDB	21	NC	Supply voltage for top-drain bias
TRG	14	I	Transfer gate
VGATE	11	I	Bias voltage for the gate of the BCD node
VSOURCE	13	I	Bias voltage for the source of the BCD node

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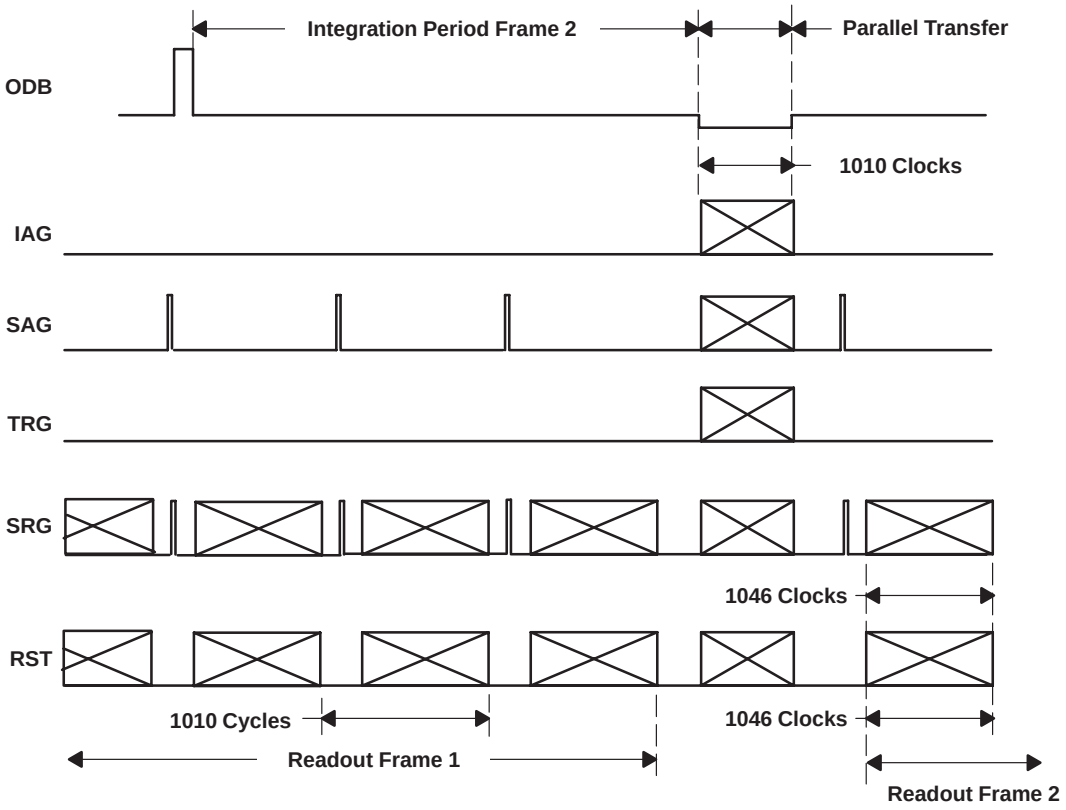

Figure 1. Overview of Frame Timing with Variable Integration

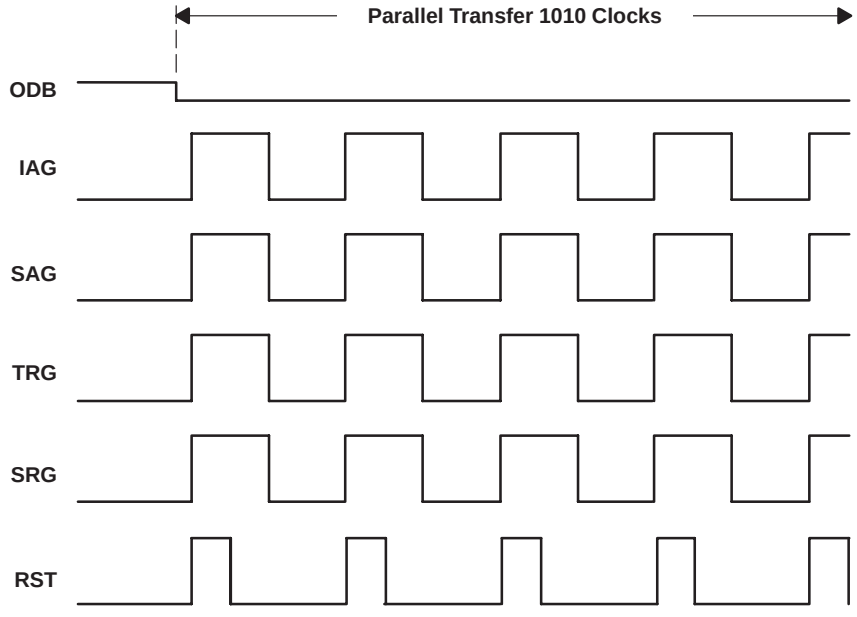

Figure 2. Expanded Parallel Transfer Timing

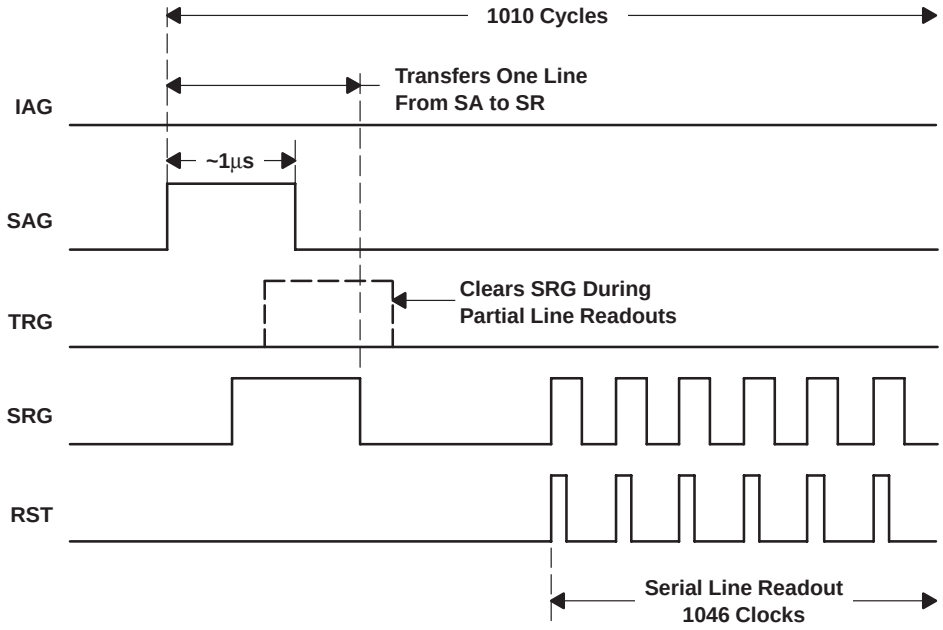

Figure 3. Expanded Storage Area-to-Serial Register Transfer and Pixel Readout Timing

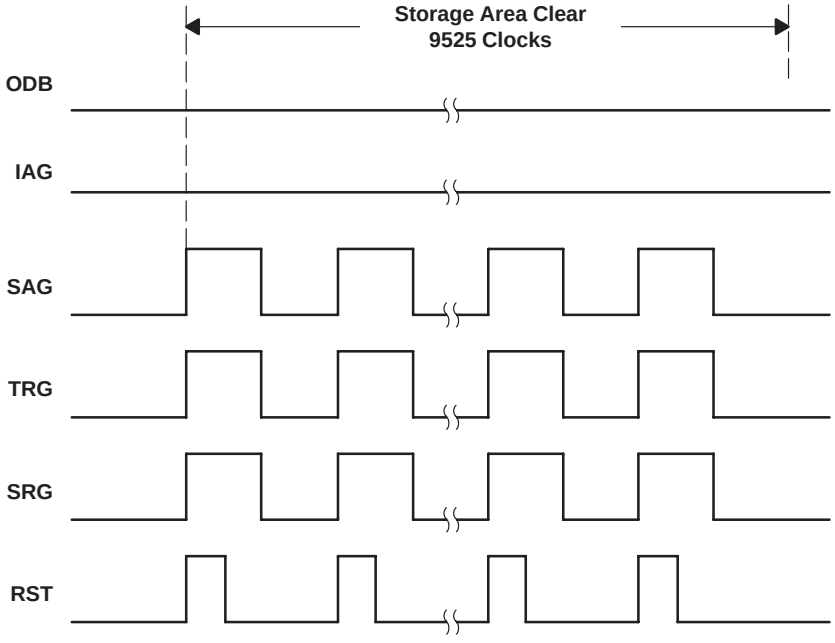

Figure 4. Special Modes of Operation: Storage Area Clear

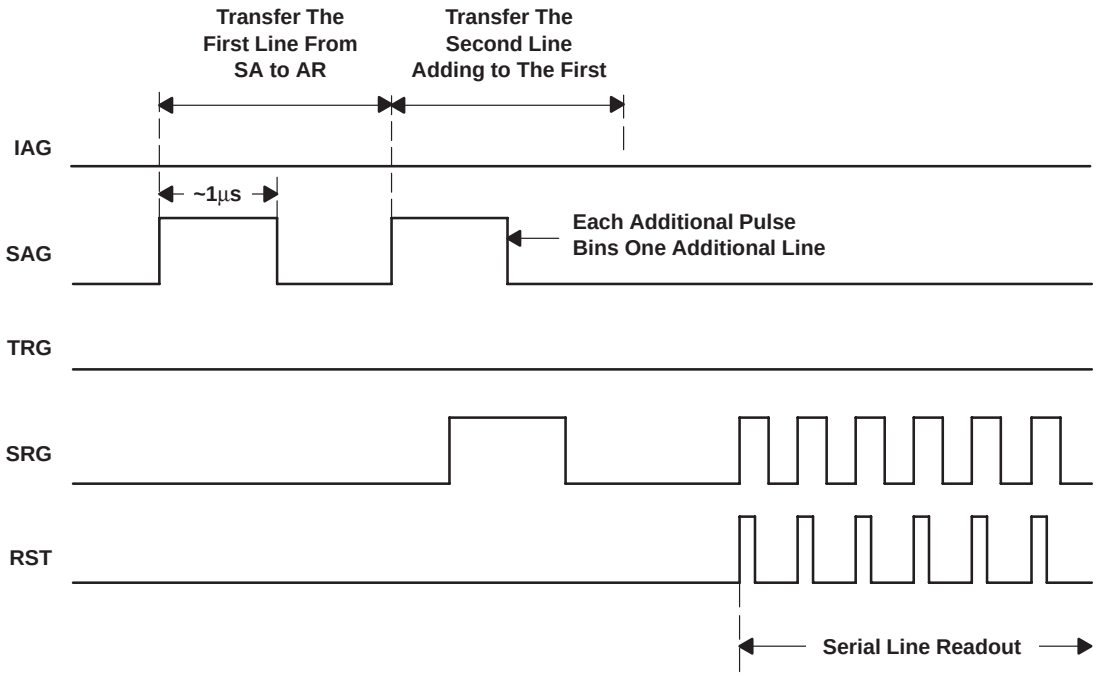

Figure 5. Special Modes of Operation: Binning

detailed description

The TC281 image sensor consists of five basic functional blocks: 1) the image-sensing area, 2) the advanced lateral overflow drain (ALOD), 3) the storage area, 4) the serial register, and 5) the bulk charge detection (BCD) node with the buffer output amplifier.

image-sensing area

The image-sensing area contains 1036 x 1010 pixel elements. A metal light shield covers 28 pixels on the left edge of the sensing area, 8 pixels on the right edge, and 10 rows at the bottom of the sensing area. The dark pixel signal can be used as a black reference during the video signal processing. The dark references will accumulate the dark current at the same rate as the active photosites, thus representing the true black level signal. As light enters the active photosites in the image area, electron hole pairs are generated and the electrons are collected in the potential wells of the pixels. The wells have a finite charge storage capacity determined by the pixel design. When the generated number of electrons in the illuminated pixels exceeds this limit, the electrons could spill over into neighboring pixels and cause blooming. To prevent this problem, each horizontal pair of pixels in the image sensing area shares a lateral overflow drain structure which provides up to a 1000-to-1 protection against such undesirable phenomenon.

advanced lateral overflow drain

The advanced lateral overflow drain structure is shared by two neighboring pixels and provides several unique features thus available in the sensor. By varying the dc bias of the drain pin, it is possible to control the blooming protection level and trade it for the well capacity.

Applying a 10-V pulse for a minimum duration of 1 us above the nominal dc bias level causes charge in the image area to be completely cleared. This feature permits a precise control of the integration time on a frame-by-frame basis. The single-pulse clear capability also reduces smear by eliminating accumulated charge from the pixels before the start of the integration (single sided smear).

ADVANCE INFORMATION

advanced lateral overflow drain (continued)

Application of a negative 2-V pulse during the parallel transfer is recommended to prevent possible artifacts from slight column-to-column pixel well capacity variations.

storage area

A metal light shield covers the storage area to prevent a further integration of charge when charge is being stored before readout. When the sensor is to be used in a single-shot mode and is dormant for a long period of time, it is necessary to perform multiple storage area clears to ensure the complete charge removal (see Figure 4).

serial register

The serial register shifts the data out of the sensor area at a maximum rate of 40 MHz, thus achieving a 1000 x 1000 pixel readout with the frame rate of 30 frames per second. The data is shifted to the BCD node on the falling edge of the SRG clocking pulses.

The data can also be transferred out of the serial registers in a parallel direction to the clear drain. This allows partial line readouts. The timing for this operating mode consists of transferring the next row from the storage into the serial register while also clocking the TRG gate. Binning of multiple pixels within a column together to increase the device sensitivity is possible by multiple line transfers into the serial register prior to the register readout. The timing for this mode of operation is shown in Figure 5. Care must be taken not to exceed the well capacity of the serial register by transferring too many lines into it. Horizontal binning is also possible in this sensor. It can be accomplished in the BCD detection node by a suitable skipping of the reset pulses.

bulk charge detection node and output amplifier

The TC281 image sensor uses a patented TI charge detection device called the bulk charge detection node. In this structure, the signal electron packets are transferred under a uniquely designed p-channel MOS transistor where they modulate the transistor threshold voltage. The threshold voltage changes are then detected and represent the desired output signal. After sensing is completed, charge is removed from the node by applying a reset pulse. One of the key advantages of the BCD charge detection concept is that charge is sensed nondestructively. The nondestructive readout does not generate reset noise, therefore, eliminating the need for the CDS post processing. Other advantages are high speed and a very low noise.

Emitter-follower output buffering is recommended for the TI image sensors. Also, it is recommended that the emitter follower be ac coupled to the rest of the signal processing chain. AC coupling eliminates problems with the sensor output dc stability and the sensor-to-sensor dc output level variations.

spurious nonuniformity specification

The spurious nonuniformity specification of the TC281 CCD grades –30 and –40 is based on several performance characteristics:

- Amplitude of the nonuniform line or pixel signal
- Polarity of the nonuniform pixel signal
  - Black
  - White
- Column signal amplitude

The CCD sensors are characterized in both an illuminated condition and a dark condition. In the dark condition, the nonuniformity is specified in terms of absolute amplitude as shown in Figure 6. In the illuminated condition, the nonuniformity is specified as a percentage of the total amplitude as shown in Figure 7.

PART NUMBER	PIXEL NONUNIFORMITY		COLUMN NONUNIFORMITY
	DARK CONDITION	ILLUMINATED CONDITION	COLUMN AMPLITUDE x (mV)
	PIXEL AMPLITUDE, x (mV)	% OF TOTAL ILLUMINATION	
TC281-30	x ≤ TBD	x ≤ TBD	x < TBD
TC281-40	x ≤ TBD	x ≤ TBD	x ≤ TBD

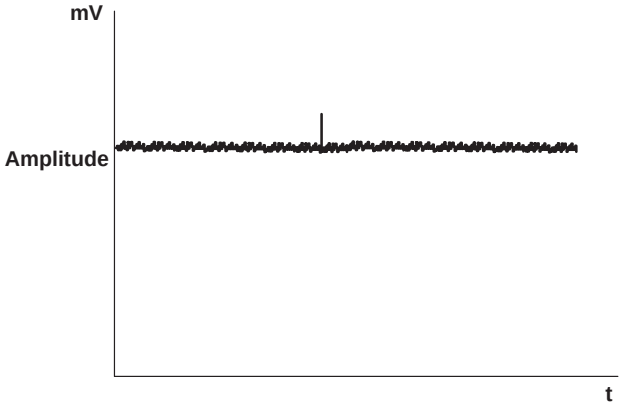

Figure 6. Pixel Nonuniformity, Dark Condition

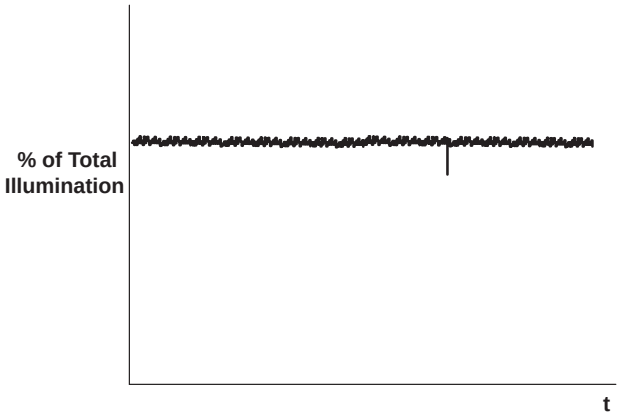

Figure 7. Pixel Nonuniformity, Illuminated Condition

absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Supply voltage range, V_{CC}: ADB, CDB, TDB, Vgate, Vsource . . . . . SUB to SUB + 15 V
Supply voltage range, V_{CC}; ODB . . . . . SUB to SUB + 21 V
Clock voltage range: IAG, SAG, SRG, RST, TRG (see Note 1) . . . . . –15 V to 15 V
Operating free-air temperature range, T_A . . . . . –10°C to 45°C
Storage temperature range, T_{STG} . . . . . –30°C to 85°C
Package temperature for guaranteed operation . . . . . –10°C to 55°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: Substrate at ground

recommended operating conditions

			MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}	ADB, CDB		11	12	13	V
Supply voltage, V_{CC}	Vsource			12		V
	Vgate			0		V
Supply voltage for ODB	Image area clearing	Vclear	14	16	18	V
	Antiblooming control	Vabc	4	6	8	
	Parallel transfer	Vxfer		Vabc–2V		
Supply current	ADB			3.5	5	mA
Substrate bias voltage				0		V
Clock voltage	Image area gate, IAG	High	1.5	2	2.5	V
		Low	–10.5	–10	–9.5	
	Storage area gate, SAG	High	1.5	2	2.5	
		Low	–10.5	–10	–9.5	
	Serial register gate, SRG	High	1.5	2	2.5	
		Low	–10.5	–10	–9.5	
	Transfer gate, TRG	High	1.5	2	2.5	
		Low	–10.5	–10	–9.5	
	Reset gate, RST	High	5	5	8	
		Low	0	0	0.5	
Clock frequency, f_{clock}	IAG, SAG			5	10	MHz
	SRG RST				40	
	TRG			5	10	

ADVANCE INFORMATION

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature

PARAMETER		MIN	TYP	MAX	UNIT
Dynamic range (see Note 2)			62		dB
Charge-conversion factor			10		μV/e
Charge-transfer efficiency (see Note 3)		0.99990	0.99995	1	
Signal-response delay time, Tau (see Note 4)			7		ns
Output resistance			310	400	Ω
Noise-equivalent signal		12	25		electrons
Supply current (see Note 5)	IDD		3.5	5	mA
Capacitance	IAG		14500		pF
	SAG		14500		
	SRG		52		
	TRG		50		
	RST		5.5		

† All typical values are used at T_A = 25°C.

NOTES: 2. Dynamic range is –20 times the logarithm of the mean-noise signal divided by the saturation-output signal.
3. Charge-transfer efficiency is one minus the charge loss per transfer in the output register. The test is performed in the dark using an electrical input signal.
4. Signal-response delay time is the time between the falling edge of the SRG pulse and the output-signal valid state.
5. V_{ADC} at 12 V and $V_{SUBSTRATE}$ at ground.

optical characteristics

PARAMETER		MIN	TYP	MAX	UNIT
Sensitivity (see Note 6)	No IR filter		240		mV/lux
	With IR filter		30		
Saturation signal, V_{sat} (see Note 7)	Antiblooming off		320		mV
Blooming overload ratio (see Note 8)		300	1000		
Image-area well capacity			32K		electrons
Smear at 5 MHz (see Notes 9 and 10)			0.06%		
Dark current	T_A = 21°C		0.4		nA/cm^2
Electronic-shutter capability		1/1000	1/30	Saturation	sec

NOTES: 6. Based on 16.67 ms integration time.
7. Saturation is the condition in which further increases in exposure do not lead to further increase in output signal.
8. Blooming-overload ratio is the ratio of blooming exposure to saturation exposure.
9. Smear is a measure of the error introduced by transferring charge through an illuminated pixel in shutterless operation. It is equivalent to the ratio of the single-pixel transfer time to the exposure time using an illuminated section that is 1/10 of the image-area vertical height with recommended clock frequencies.
10. The exposure time is 16.67 ms, the fast dump clocking rate during vertical timing is 10 MHz, and the illuminated section is 1/10 of the height of the image section.

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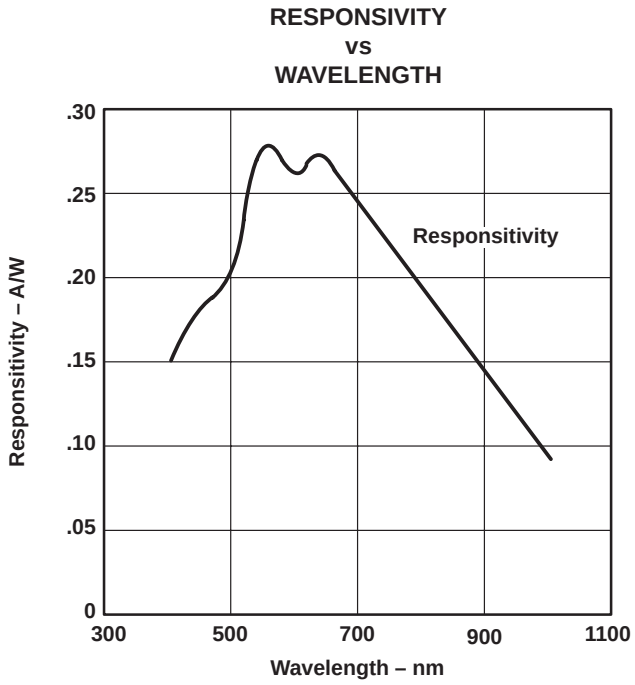

Figure 8. Typical Spectral Responsivity

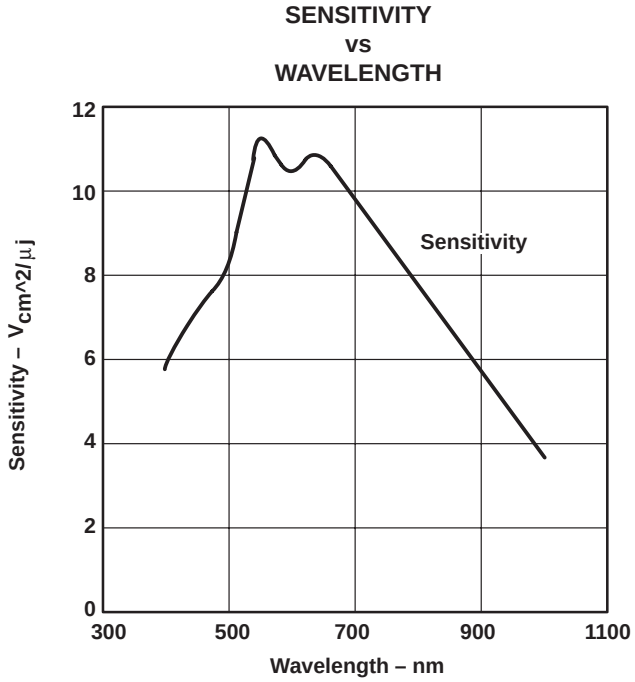

Figure 9. Typical Spectral Sensitivity

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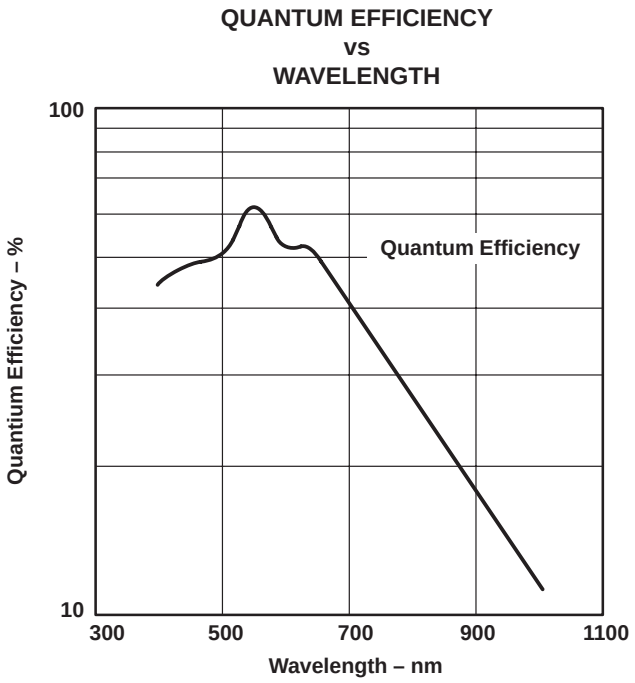

Figure 10. Typical Spectral Quantum Efficiency

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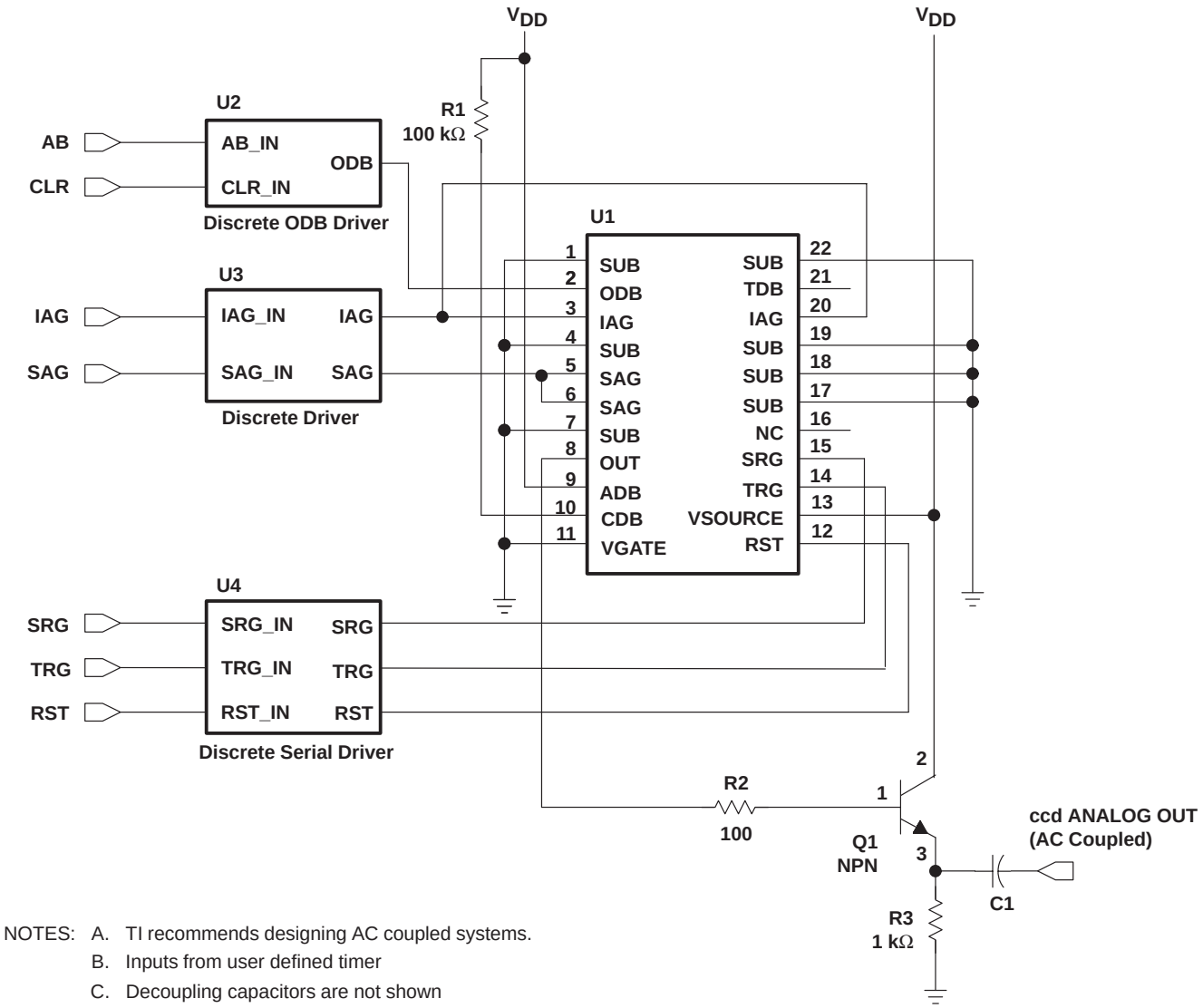
APPLICATION INFORMATION



NOTES: A. TI recommends designing AC coupled systems.
B. Inputs from user defined timer
C. Decoupling capacitors are not shown

Figure 11. Typical Application Circuit

Table 1. Supply Voltages for Application Circuits

SUPPLY	VOLTAGE
V_{DD}	12 V
V_{CC}	2 V
V_{AA}	–10 V
V_{RST}	5–8 V

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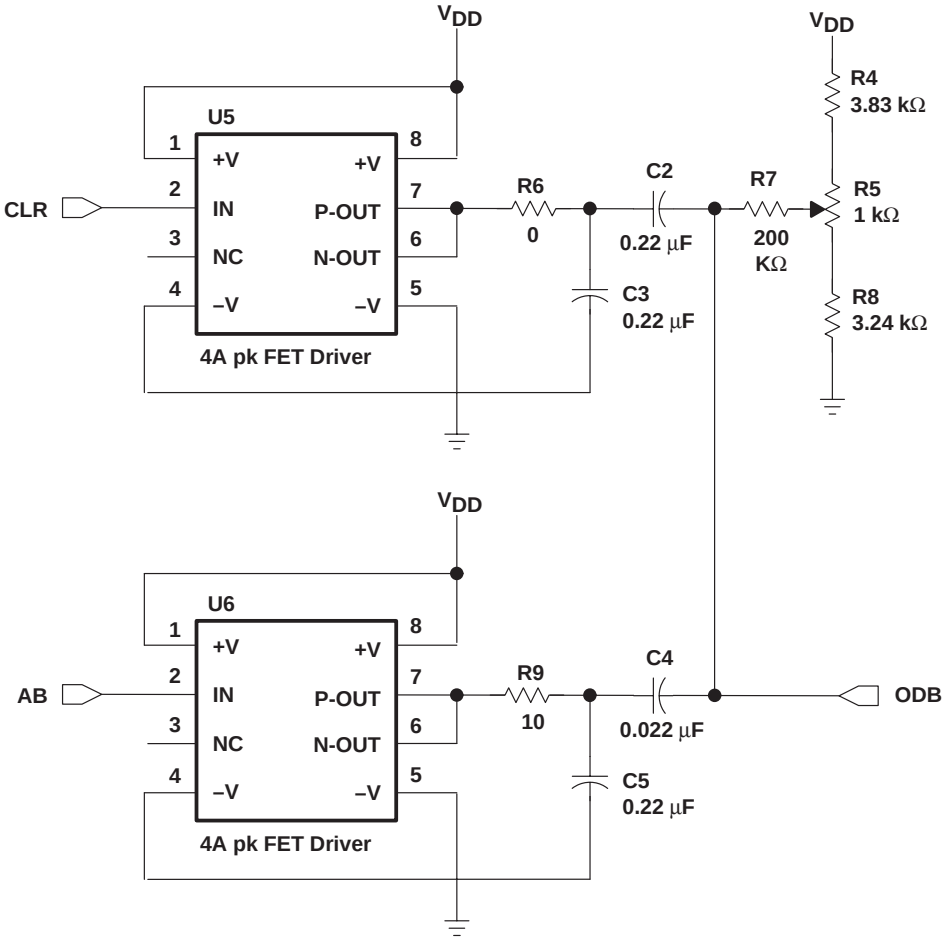
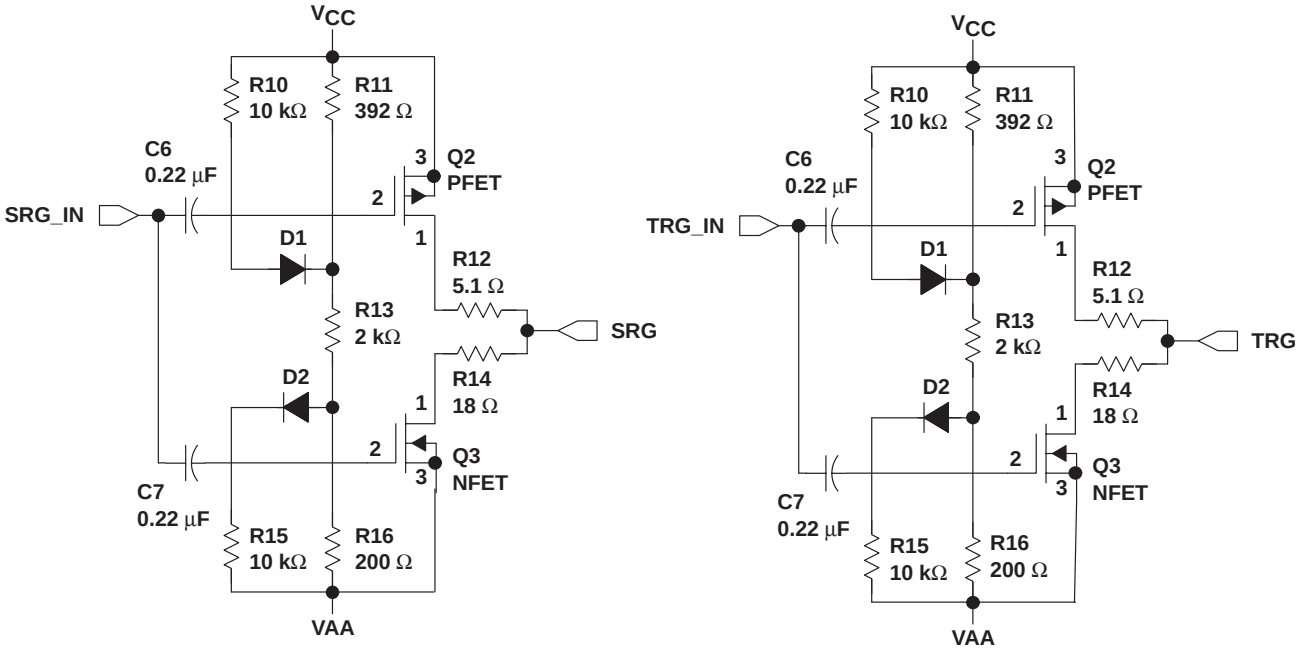
APPLICATION INFORMATION



NOTES: A. MOSFET driver with a 4A peak current and 2 Ω output resistance (see Figure 14).
B. Image area clear (CLR) is active high while the parallel transfer (AB) is active low. These two pulses will generate the timing for ODB, as shown in Figure 1.
C. Decoupling capacitors are not shown

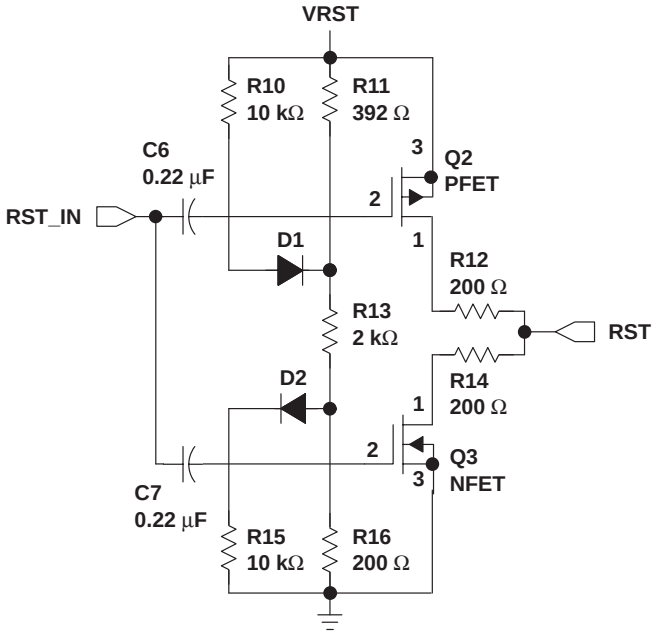
Figure 12. Typical ODB Driver Circuit

APPLICATION INFORMATION



NOTE A: Decoupling capacitors are not shown

Figure 13. Typical Serial/Transfer Driver Circuits



NOTE A: Decoupling capacitors are not shown

Figure 14. Typical Reset Driver Circuit

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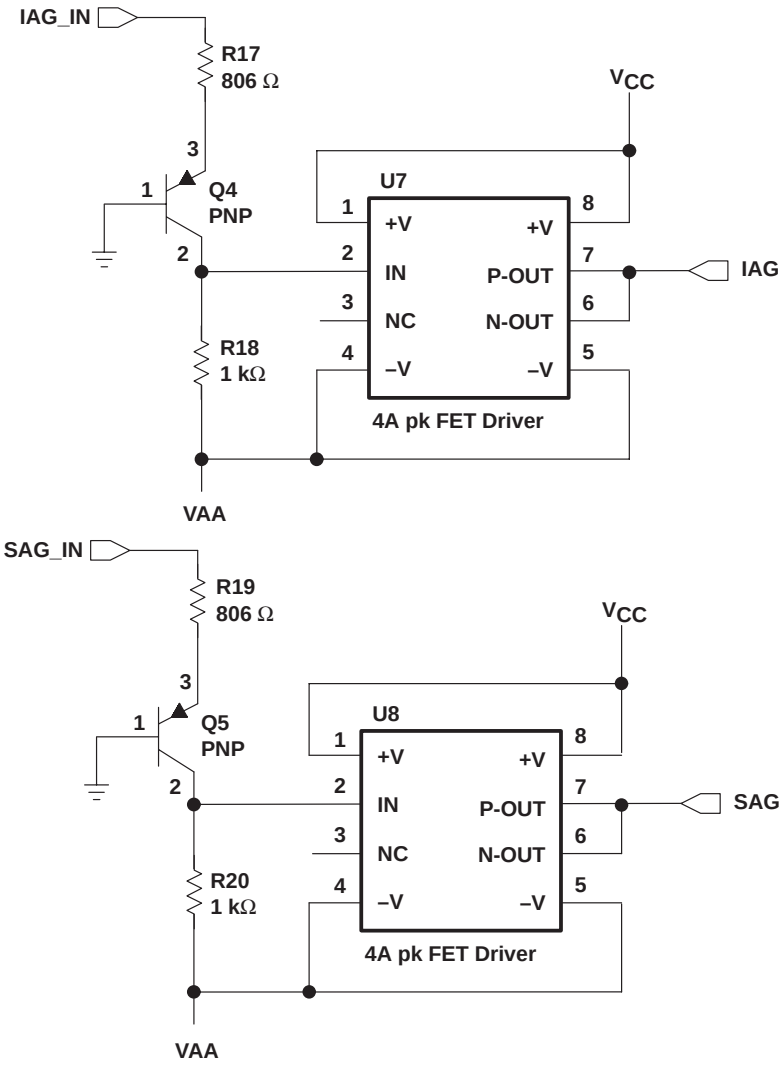
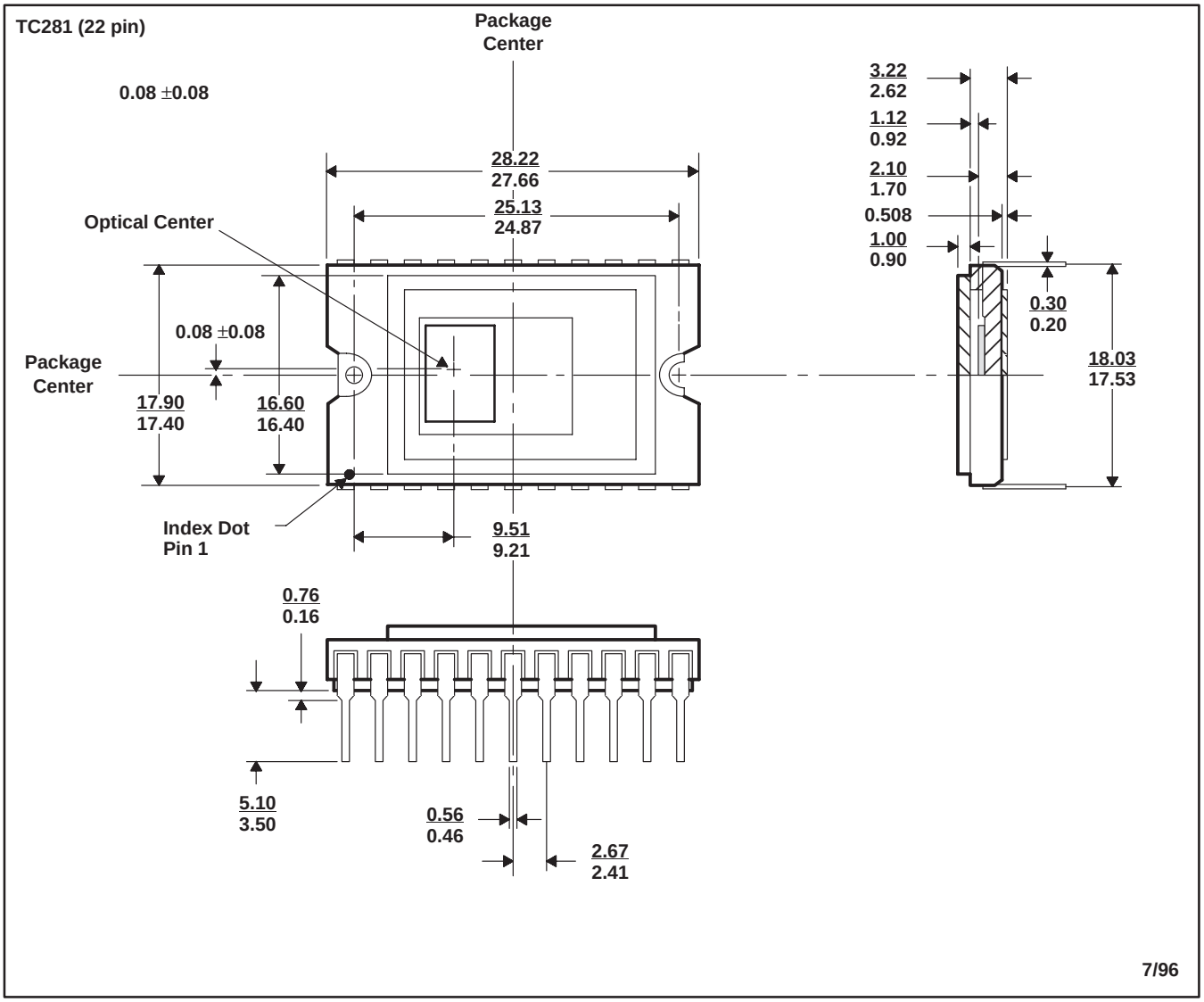


NOTES: A. MOSFET driver with a 4A peak current and 2 Ω output resistance (see Figure 13).
B. Decoupling capacitors are are not shown.

Figure 15. Typical Parallel Driver Circuit

MECHANICAL DATA

The package for the TC281 consists of a ceramic base, a glass window, and a 22-lead frame. The package leads are configured in a dual in-line organization and fit into mounting holes with 2,54 mm (0.10 in) center-to-center spacing. The glass window is sealed to the package by an epoxy adhesive. It can be cleaned by any standard procedure for cleaning optical assemblies or by wiping the surface with a cotton swab moistened with alcohol.



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NOTES: A. All linear dimensions are in millimeters.
B. Single dimensions are nominal.
C. The center of the package and the center of the image area are not coincident.
D. Each pin centerline is located within 0,25 mm (0.010 in) of its true longitudinal position.

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