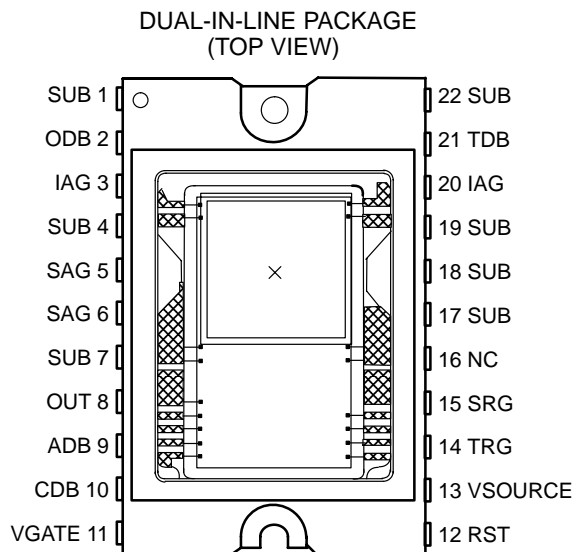


- **High-Resolution, Solid-State Frame-Transfer Image Sensor**
- **11.3-mm Image Area Diagonal**
- **1000 (H) x 1000 (V) Active Elements**
- **Up to 30 Frames per Second**
- **8- $\mu$ m Square Pixels**
- **Low Dark Current**
- **Advanced Lateral Overflow Drain for Antiblooming**
- **Single-Pulse Image Area Clear Capability**
- **Dynamic Range of More Than 60 dB**
- **High Sensitivity and Quantum Efficiency**
- **Nondestructive Charge Detection Through Texas Instruments Advanced BCD Node Technology**
- **High Near-Infrared (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 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- $\mu$ m 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 device 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  $\mu$ s. After the image capture is completed (integration time) and the image is transferred into the storage, 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 must be cleared of all charge, charge can be transferred quickly across the serial registers into the clearing drain located below the register.

A high performance bulk charge detection (BCD) node 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.



This MOS device contains limited built-in gate protection. During storage or handling, the device leads should be shorted together or the device should be placed in conductive foam. In a circuit, unused inputs should always be connected to  $V_{SS}$ . Under no circumstances should pin voltages exceed absolute maximum ratings. Avoid shorting OUT to  $V_{SS}$  during operation to prevent damage to the amplifier. The device can also be damaged if the output terminals are reverse-biased and an excessive current is allowed to flow. Specific guidelines for handling devices of this type are contained in the publication *Guidelines for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices and Assemblies* available from Texas Instruments.



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# TC281

## 1036- × 1010-PIXEL CCD IMAGE SENSOR

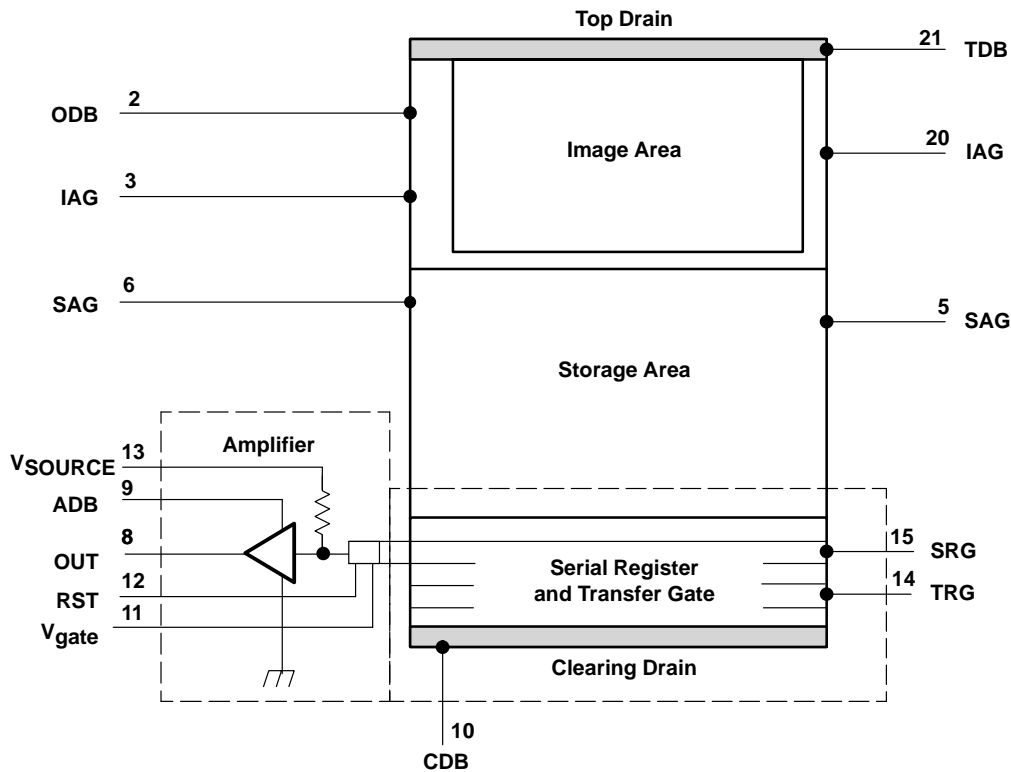
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### description (continued)

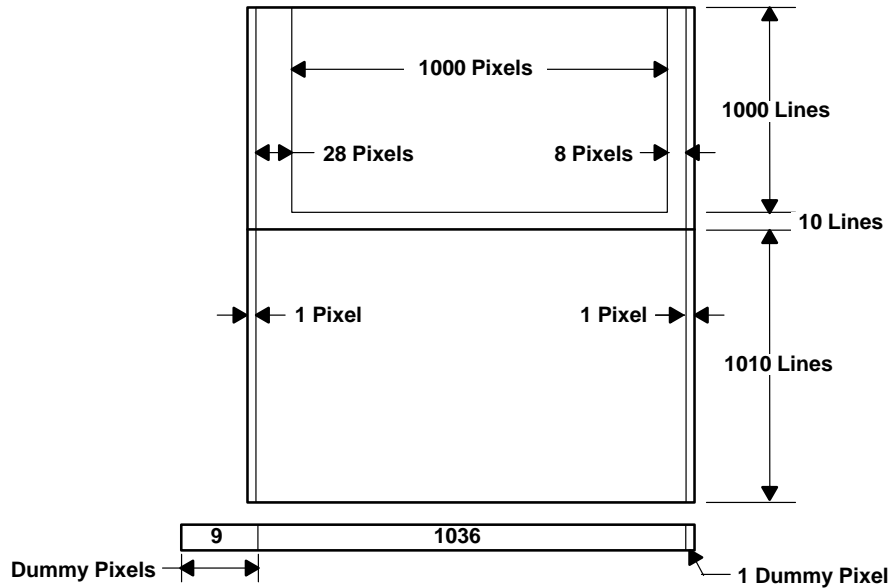
The blooming protection of the sensor is based on an advanced lateral overflow drain (ALOD). The antiblooming function is activated when a suitable dc bias is applied to the overflow drain pin. With this type of blooming protection it is also possible to clear the image area of charge completely. This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

The TC281 image sensor uses TI-proprietary advanced virtual-phase (AVP) technology, the advanced lateral overflow drain, 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 single-phase clocking. The TC281 is characterized for operation from -10°C to 45°C.

### functional block diagram



**sensor topology diagram**

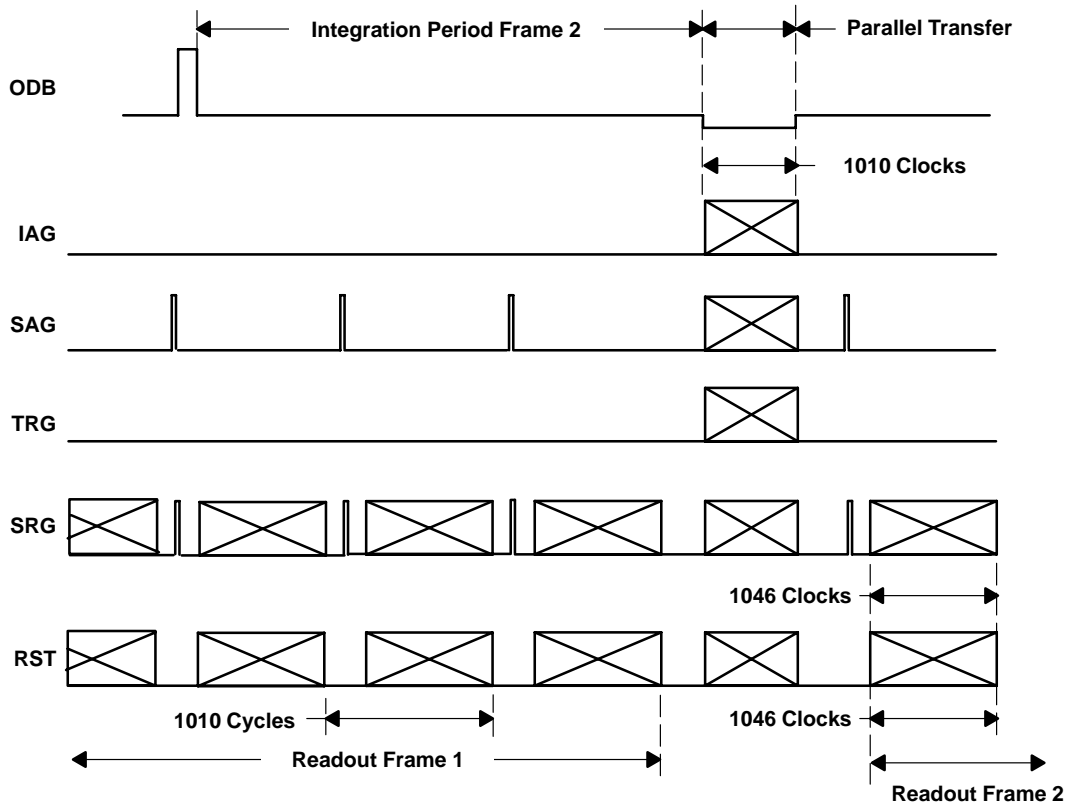


**Terminal Functions**

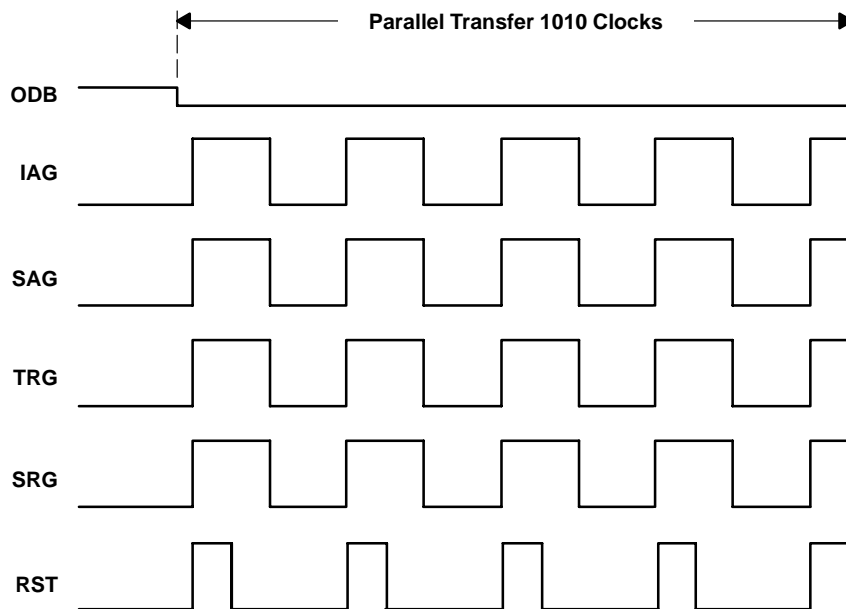
| TERMINAL<br>NAME | NO.                        | I/O | DESCRIPTION                                     |
|------------------|----------------------------|-----|---|
| ADB              | 9                          | I   | Supply voltage for amplifier drain bias         |
| CDB              | 10                         | I   | Supply voltage for clearing drain bias          |
| IAG              | 3, 20                      | I   | Image area gate                                 |
| NC               | 16                         |     | No internal connection                          |
| 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                            |
| SUB              | 1, 4, 7, 17,<br>18, 19, 22 |     | Substrate and clock return                      |
| TDB              | 21                         | NC  | Supply voltage for test diode                   |
| 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     |

**TC281**  
**1036- × 1010-PIXEL CCD IMAGE SENSOR**

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**Figure 1. Overview of Frame Timing with Variable Integration**



**Figure 2. Expanded Parallel Transfer Timing**

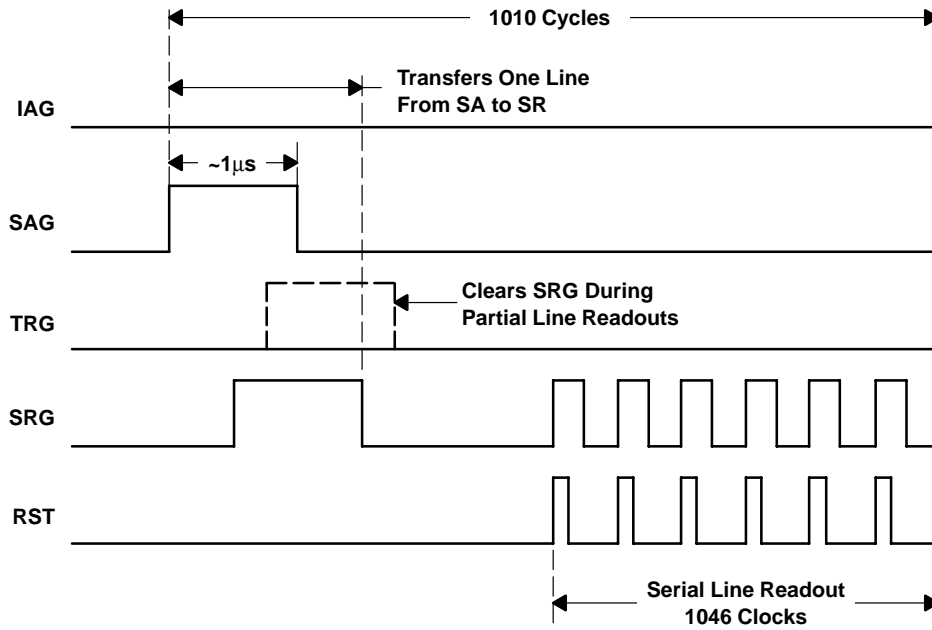


Figure 3. Expanded Storage Area-to-Serial Register Transfer and Pixel Readout Timing

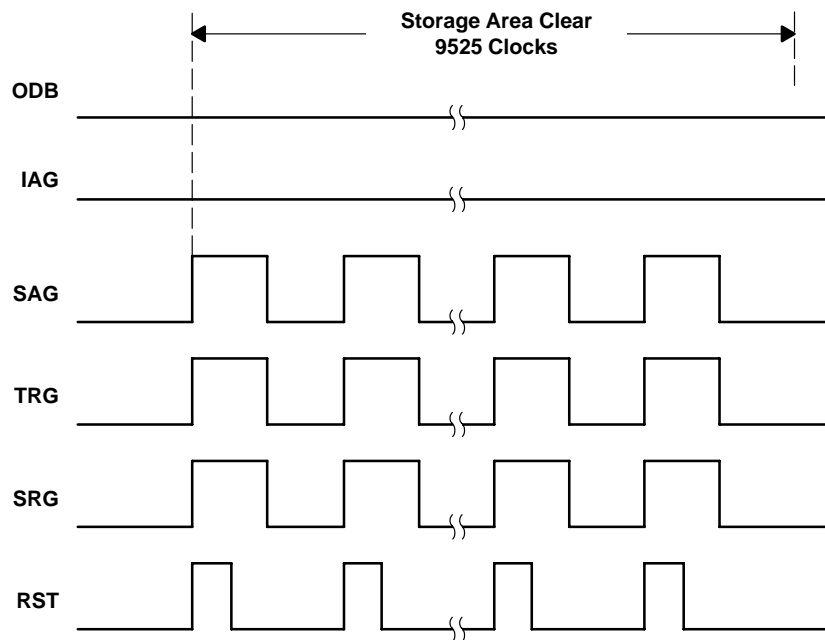


Figure 4. Special Modes of Operation: Storage Area Clear

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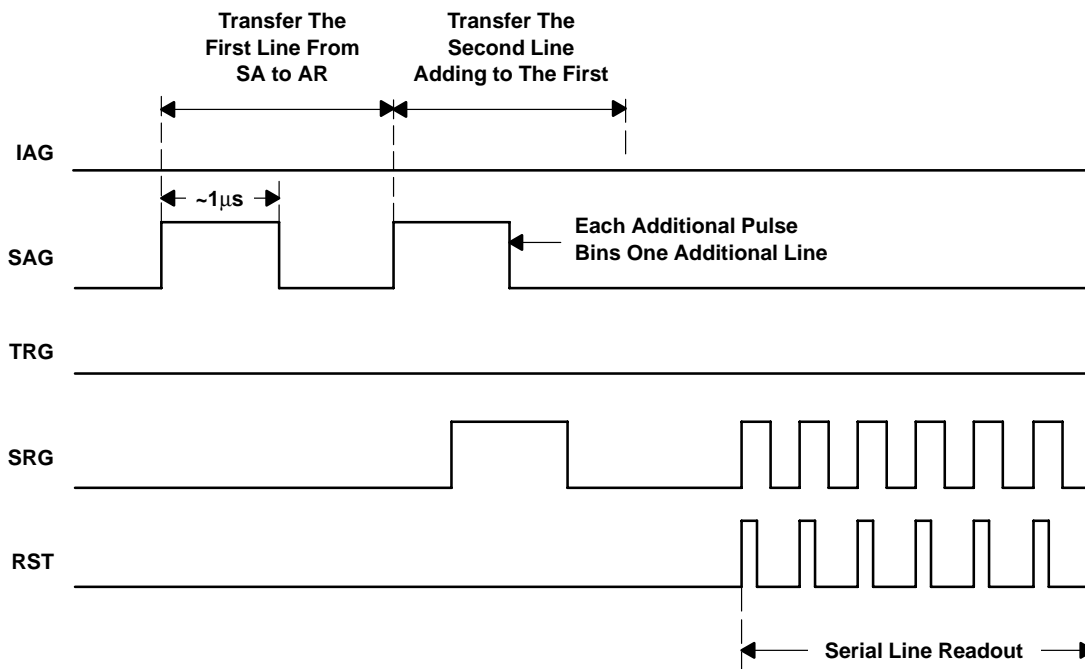


Figure 5. Special Modes of Operation: Binning

## detailed description

The TC281 image sensor consists of five basic functional blocks:

- Image-sensing area
- ALOD
- Storage area
- Serial register
- 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 is used as a black reference during the video signal processing. The dark references 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 can spill over into neighboring pixels and cause blooming. To prevent this, 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 phenomena.

## advanced lateral overflow drain

The advanced lateral overflow drain structure is shared by two neighboring pixels and provides several unique features in the sensor. By varying the dc bias of the drain pin, the blooming protection level can be controlled and traded for the well capacity.

---

### advanced lateral overflow drain (continued)

Applying a 10-V pulse for a minimum duration of 1  $\mu$ s above the nominal dc bias level causes the 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).

Application of a negative 2-V pulse during the parallel transfer is recommended to prevent possible artifacts resulting 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. To use the sensor in a single-shot mode after being dormant for a long period of time, you must 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. Binning of multiple pixels within a column to increase the device sensitivity can be performed 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 node, 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; they 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, eliminating the need for the CDS post processing. Other advantages are high speed and low noise.

Emitter-follower output buffering is recommended for the TI image sensors. TI also recommends 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.

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## spurious nonuniformity specification

The spurious nonuniformity specification of the TC281 CCD grade –30 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<br>x (mV) |
|             | PIXEL AMPLITUDE, x (mV) | % OF TOTAL ILLUMINATION |                            |
| TC281-30    | <24                     | <30%                    | <0.6 mV                    |

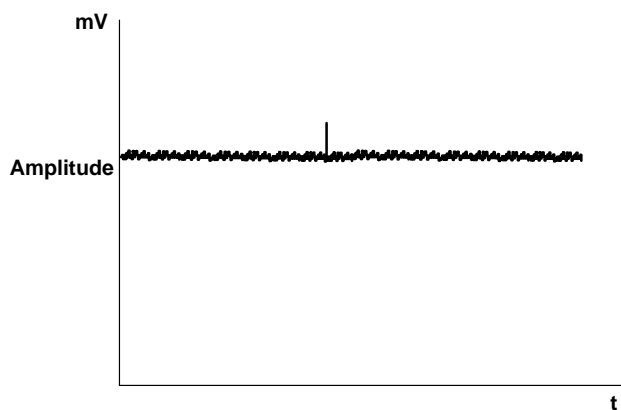


Figure 6. Pixel Nonuniformity, Dark Condition

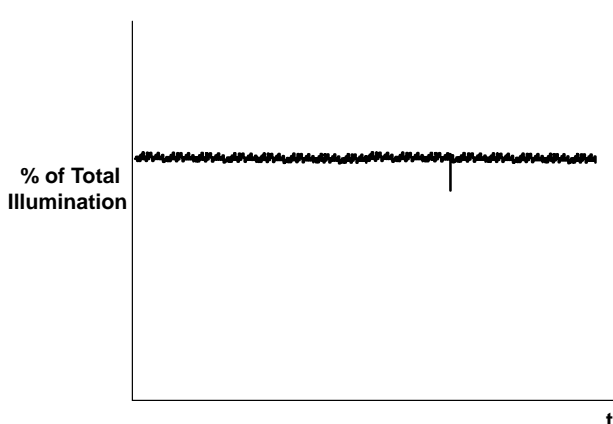


Figure 7. Pixel Nonuniformity, Illuminated Condition



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

|  |                   |
|--|-------------------|
| Supply voltage range, ADB, CDB, TDB, Vgate, Vsource .....  | SUB to SUB + 15 V |
| Supply voltage range, ODB .....                            | SUB to SUB + 21 V |
| Clock voltage range: IAG, SAG, SRG, TRG (see Note 1) ..... | -15 V to 15 V     |
| Clock input voltage range: RST .....                       | -0 V to +10 V     |
| Operating free-air temperature range, T <sub>A</sub> ..... | -10°C to 45°C     |
| Storage temperature range, T <sub>stg</sub> .....          | -30°C to 85°C     |
| Package temperature for ensured 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 <sub>CC</sub> | ADB, CDB                            |          | 11    | 12   | 13   | V    |     |  |
|                                 | Vsource                             |          | 12    |      |      |      |     |  |
|                                 | Vgate                               |          | 0     |      |      |      |     |  |
| Supply voltage for ODB          | Image area clearing                 | Vclear   | 15    | 15.5 | 16   | V    |     |  |
|                                 | Antiblooming control                | Vabc     | 5     | 5.5  | 6    |      |     |  |
|                                 | Parallel transfer                   | Vxfer    | 4     | 4.5  | 5    |      |     |  |
| 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 <sub>clock</sub> | IAG, SAG |       | 5    |      |      | MHz |  |
|                                 |                                     | SRG RST  |       | 40   |      |      |     |  |
| TRG                             |                                     | 5        |       |      |      |      |     |  |

# TC281

## 1036- × 1010-PIXEL CCD IMAGE SENSOR

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### 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      |     | $\mu\text{V}/e$ |
| 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 | $\Omega$        |
| Noise-equivalent signal                         |     | 12      | 25      |     | electrons       |
| Supply current (see Note 5)                     | IDD |         | 3.5     | 5   | mA              |
|   | IAG |         | 14500   |     | pF              |
| Capacitance                                     | SAG |         | 14500   |     |                 |
|   | SRG |         | 52      |     |                 |
|   | TRG |         | 50      |     |                 |
|   | RST |         | 5.5     |     |                 |

† All typical values are used at  $T_A = 25^\circ\text{C}$ .

- NOTES:
- Dynamic range is  $-20$  times the logarithm of the mean-noise signal divided by the saturation-output signal.
  - 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.
  - Signal-response delay time is the time between the falling edge of the SRG pulse and the output-signal valid state.
  - $V_{\text{ADC}}$  at 12 V and  $V_{\text{SUBSTRATE}}$  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, $V_{\text{sat}}$ (see Note 7) | Antiblooming disabled    | 320    |       |            | mV                 |
| Maximum usable signal, $V_{\text{USE}}$          | Antiblooming disabled    | 120    |       |            | 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                                     | $T_A = 21^\circ\text{C}$ |        | 0.3   |            | nA/cm <sup>2</sup> |
| Electronic-shutter capability                    |                          | 1/1000 | 1/30  | Saturation | sec                |

- NOTES:
- Based on 16.67 ms integration time.
  - Saturation is the condition in which further increases in exposure do not lead to further increase in output signal.
  - Blooming-overload ratio is the ratio of blooming exposure to saturation exposure.
  - 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.
  - 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.



TYPICAL CHARACTERISTICS

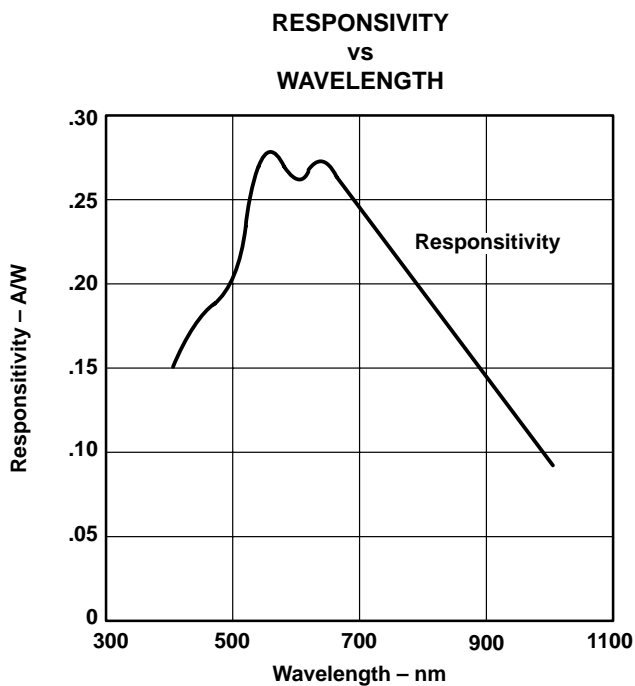


Figure 8. Typical Spectral Responsivity

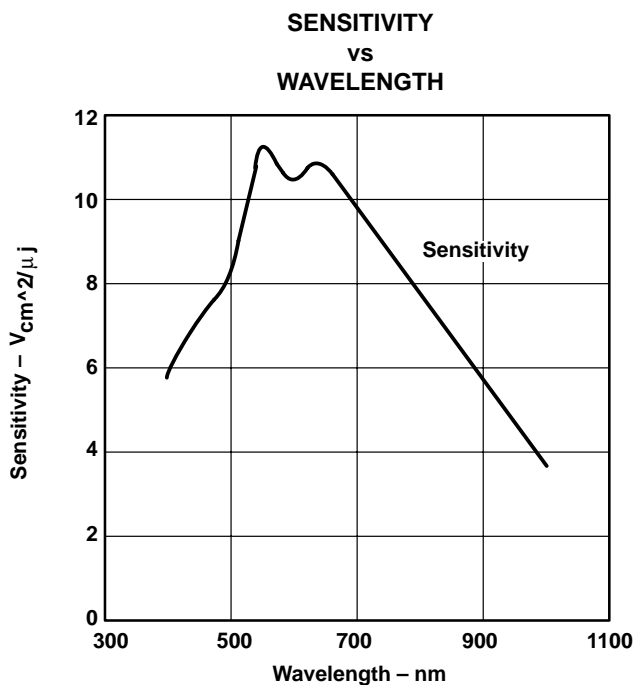


Figure 9. Typical Spectral Sensitivity

TYPICAL CHARACTERISTICS

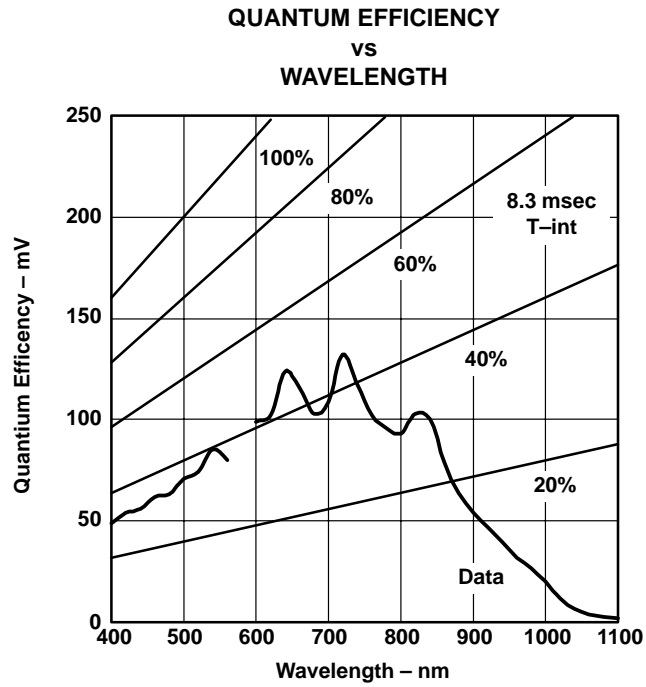


Figure 10. Typical Spectral Quantum Efficiency

APPLICATION INFORMATION

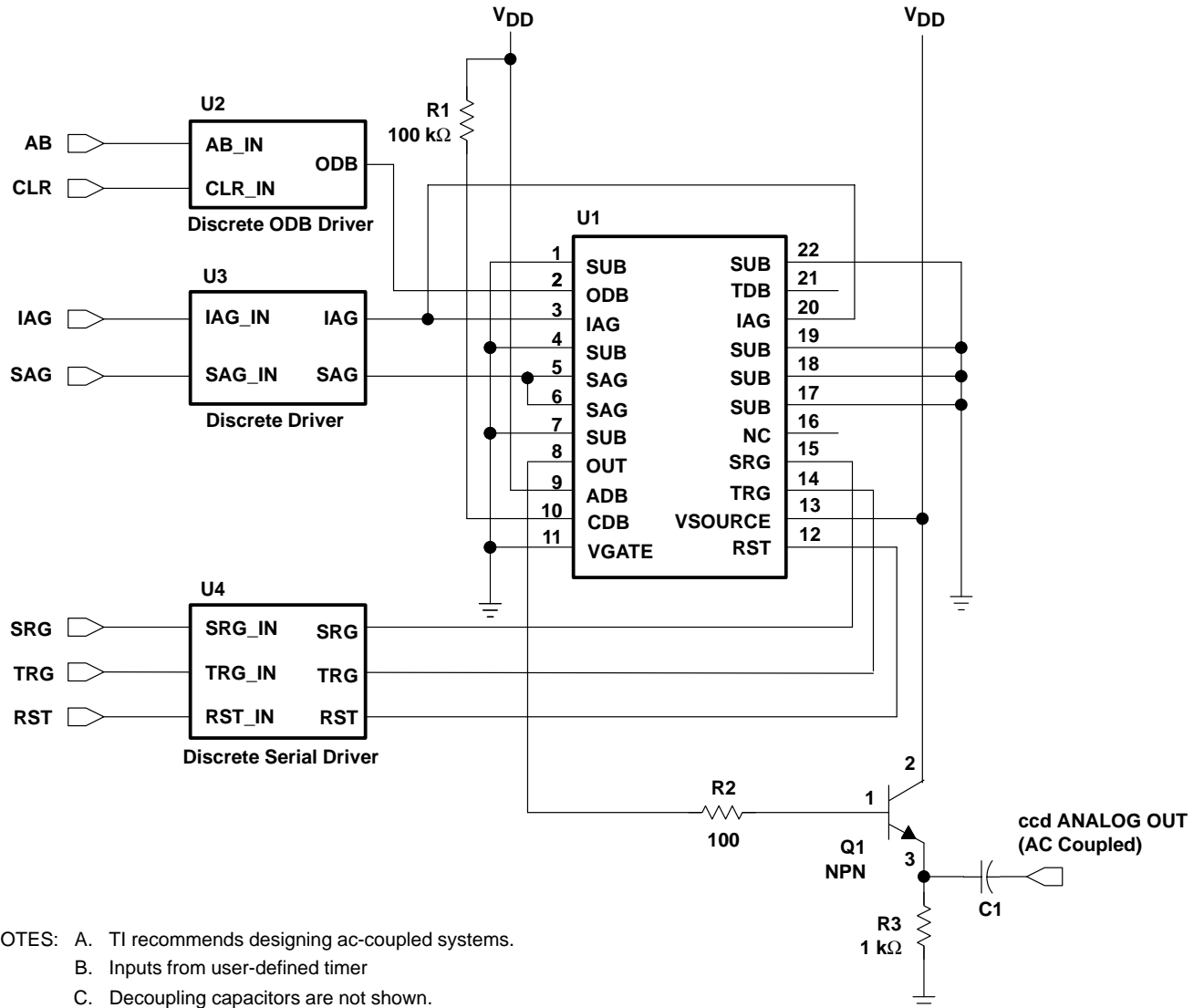
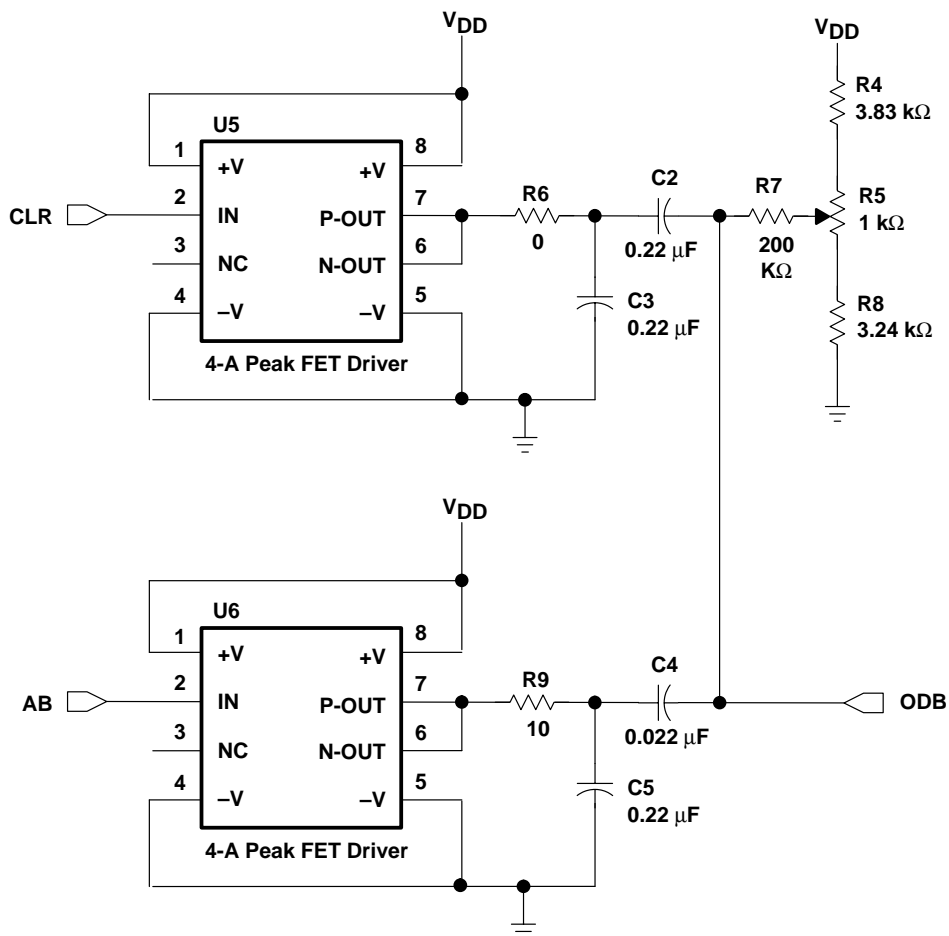


Figure 11. Typical Application Circuit

Table 1. Supply Voltages for Application Circuits

| SUPPLY           | VOLTAGE |
|------------------|---------|
| V <sub>DD</sub>  | 12 V    |
| V <sub>CC</sub>  | 2 V     |
| V <sub>AA</sub>  | -10 V   |
| V <sub>RST</sub> | 5–8 V   |

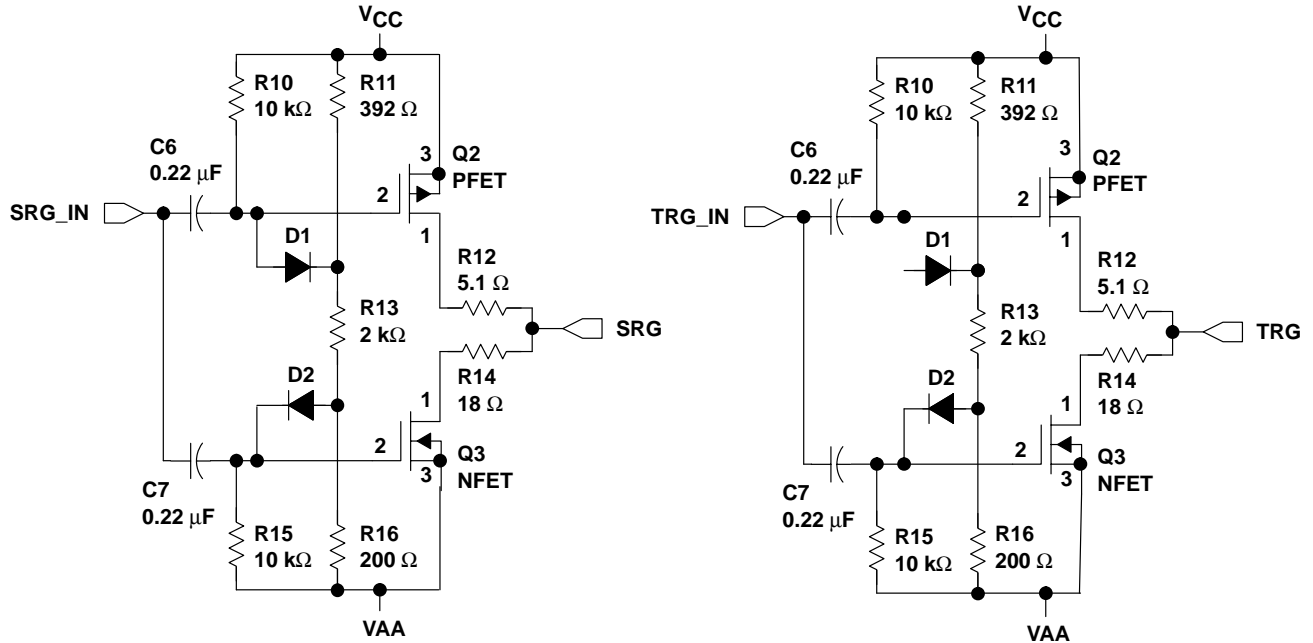
**APPLICATION INFORMATION**



- NOTES: A. MOSFET driver with a 4-A peak current and a 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 generate the timing for ODB, as shown in Figure 1.  
 C. Decoupling capacitors are not shown.

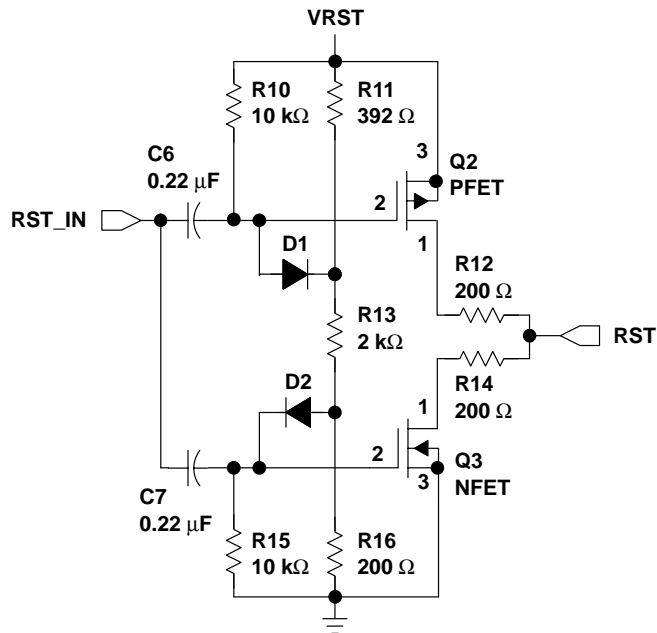
**Figure 12. Typical ODB Driver Circuit**

APPLICATION INFORMATION



NOTE A: Decoupling capacitors are not shown.

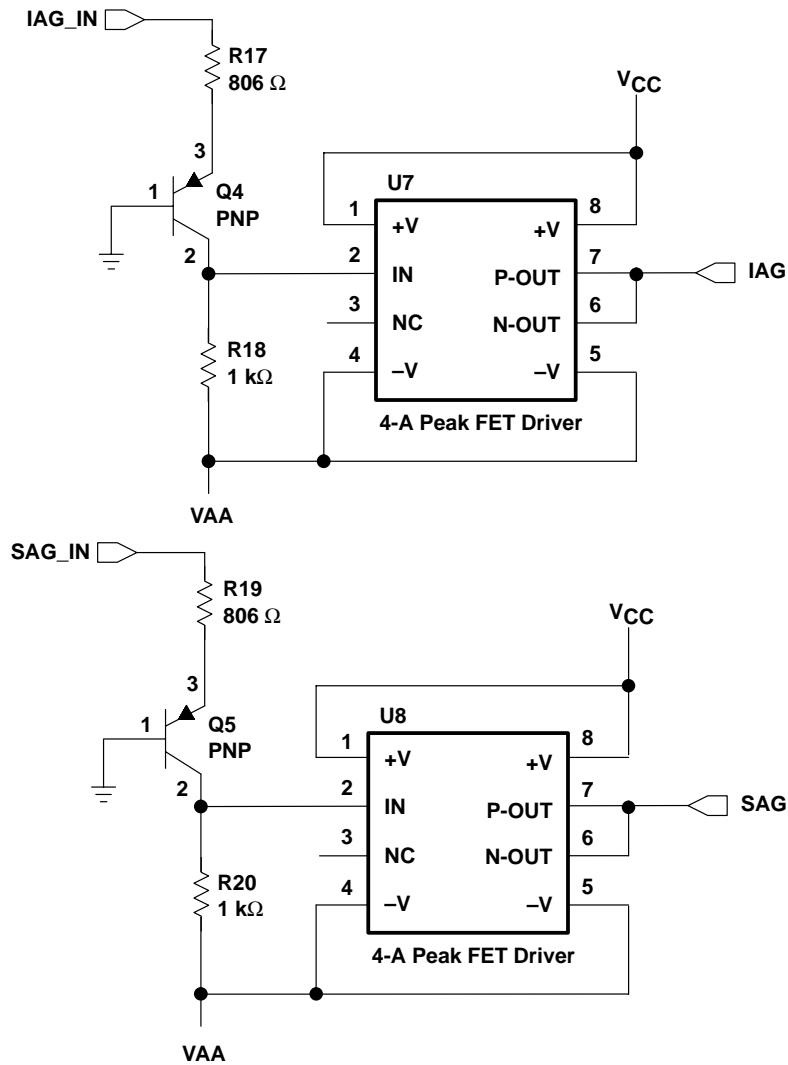
Figure 13. Typical Serial/Transfer Driver Circuits



NOTE A: Decoupling capacitors are not shown.

Figure 14. Typical Reset Driver Circuit

**APPLICATION INFORMATION**



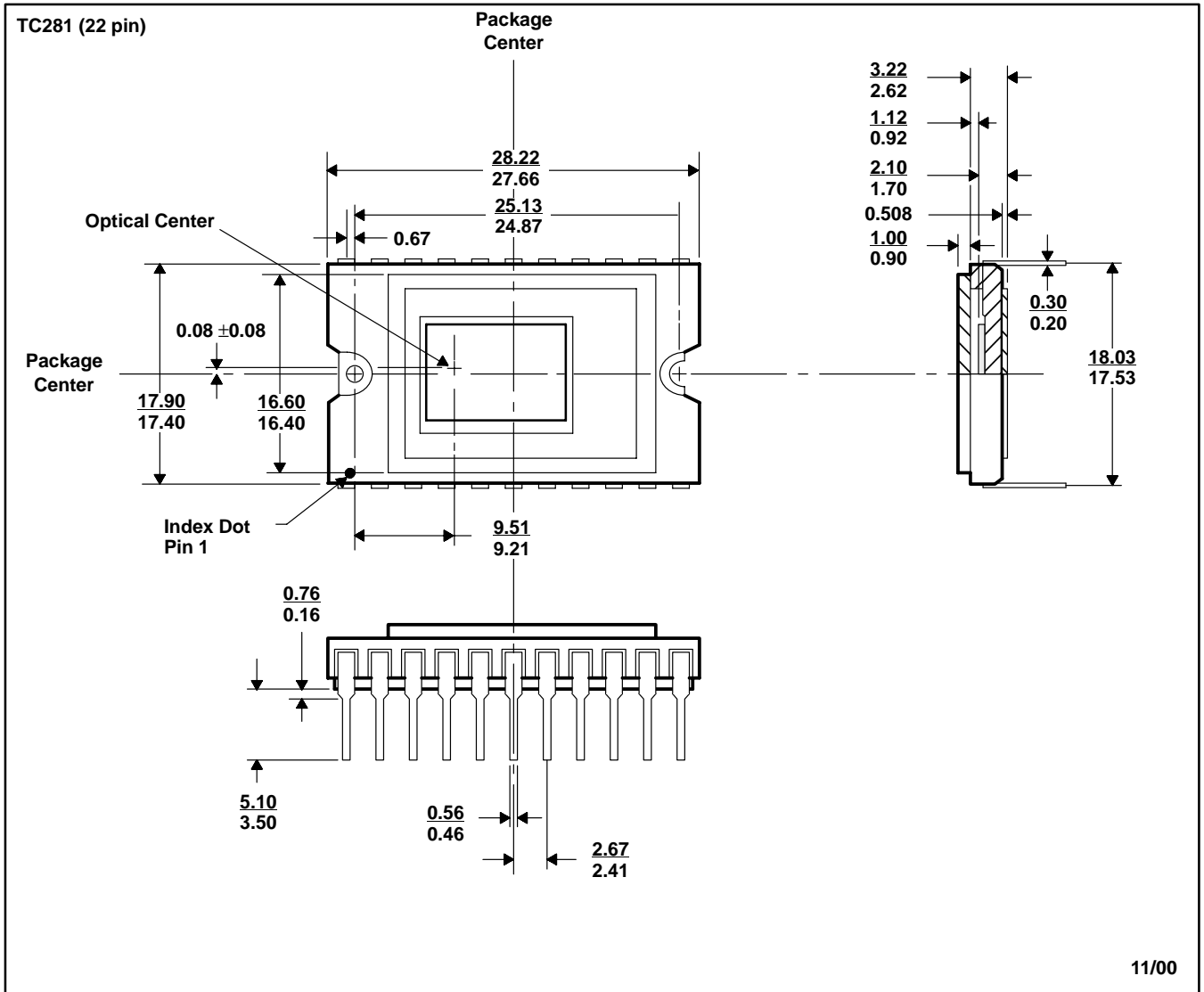
- NOTES: A. MOSFET driver with a 4-A peak current and a 2-Ω output resistance (see Figure 13).  
 B. Decoupling capacitors are not shown.

**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.



- 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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### Mailing Address:

Texas Instruments  
Post Office Box 655303  
Dallas, Texas 75265