INTELLIGENT OPTO SENSOR

DESIGNER'S NOTEBOOK

TAOS TEXAS ADVANCED OPTOELECTRONIC SOLUTIONS®

Using the TSL1401R Linear Array

Transitioning from the TSL1401 to the TSL1401R

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Introduction

The TSL1401R is designed to be a pin-compatible substitute for the TSL1401. Designed with portable, high-performance applications in mind, the TSL1401R operates at a supply voltage down to 3V, has a rail-to-rail output voltage swing, has improved dark-signal non-uniformity, and higher speed operation. Although overall it is a higher performance device, any parametric changes can raise issues in a system if the designer has not considered them. Therefore, it is the intent of this document to highlight the major differences between the TSL1401 and TSL1401R devices, and point out some system considerations that will help ensure a smooth transition from the TSL1401 to the TSL1401R.

Overview of Differences

This section will begin with a summary list of the significant specification differences between the TSL1401 and TSL1401R. This list, in no particular order, can be found in Table 1. Following is a short description of each parameter, and how it might influence the performance of a system.

Table 1 - Summary of Differences

PARAMETER	TSL1401	TSL1401R
Supply Voltage, VDD	4.5V - 5.5V	3V - 5.5V
Output Type	Open-Drain	op-amp type*
Load Required	330 ohm typical	no load required
Max. Output Swing (VAOsat)	3V, VDD = 5V	4.5V, VDD = 5V
Max. Clock Frequency	2MHz	8MHz
Output settling time, ts	350ns	120ns
Supply Current, IDD	4mA	4.5mA
DSNU	0.12V	0.05V

* The TSL1401 had an open-drain output which could only pull up, requiring a pull-down resistor to operate. The TSL1401R has an active low / active high op-amp type output which can swing rail-to-rail (under no or light load conditions) and does not require a pull-down resistor, although in some cases, as with capacitive loads, a pull-down resistor can decrease output transition times.

Supply Voltage
Probably the biggest difference between the TSL1401 and TSL1401R from an electrical point of view is the TSL1401R is designed to operate with a supply voltage down to 3V. This allows the device to be used in battery-operated systems with microcontrollers and analog-to-digital converters (ADCs) operating at 3V. The inputs are TTL-compatible at both 3V and 5V.

Analog Output
The analog output (Ao) of the TSL1401R has been changed from a source-follower type output, which required a pull-down resistor, to a class A-B type push-pull output stage typical of op-amps. This type of output requires no pull-down resistor since it is active in both directions (pull-up and pull-down). Another key feature of the TSL1401R output is that is will swing rail-to-rail, which means the output voltage will go down within millivolts of ground (or as low as the pixel dark level will allow) and within millivolts of the supply voltage under no-load conditions. As the load to ground is increased, the maximum output voltage swing, or the ability of the output to pull up, is reduced.

The push-pull output of the TSL1401R is able to drive large capacitive loads and resistive loads as low as 50 ohms (see the TSL1401R datasheet for details). Although a load resistor is not required, for some cases of output capacitance a load resistor helps improve the settling time.

One possible issue that can arise from the extended output swing of the TSL1401R is that threshold circuitry or software algorithms may be affected by the higher output voltage levels obtained when operating at 5V. The TSL1401 has a saturation, or maximum output, voltage of 3V to 3.5V with a 5V supply. Therefore, at the saturation light level, all pixels would "max out" at the saturation voltage, resulting in a very flat, consistent output across the array. This is because the saturation voltage is nearly the same for all the pixels. Under the same light condition, the TSL1401R will not be saturated, due to its extended range, or "headroom", on the output. Therefore, the actual optical signal pattern, rather than the saturation level, will appear across the array. This will most likely appear much more non-uniform than the saturated TSL1401, due to lighting, PRNU, and optical non-uniformities.

Another consideration of output swing is to ensure that subsequent circuitry can tolerate the higher voltage swing of the TSL1401R. Some ADCs or amplifiers may not be able to handle an input range which includes the supply voltage. Or, if a separate power supplies are used for the linear array and the processing circuitry, for example 5V on the linear array and 3V on the processing circuitry, the 3V circuit may not be able to handle the 5V coming from the TSL1401R on its input.

Clock Frequency
The analog output of the TSL1401R has a faster response time than that of the TSL1401, and therefore has a higher maximum clock frequency specification. The maximum specified clock frequency of the linear array determines the maximum pixel rate, or the rate the pixels can be clocked out, in pixels-per-second. Rather than a true clock rate limitation, this limitation is actually determined by the settling time of the analog output. When maximum clock rate is specified on the TAOS datasheet, it is based on the criteria that the output must settle to within 1% during the clock period. Therefore, if the settling time is 120ns, this implies a maximum clock frequency of 8MHz (125ns period). Again, this is not a limitation of the digital clock circuitry or shift register. Therefore, if an application does not require precise settling of the output voltage value, higher clock rates can be used. Examples of such applications might be edge detection or optical encoding, where the output fed into a comparator for "black and white" thresholding.

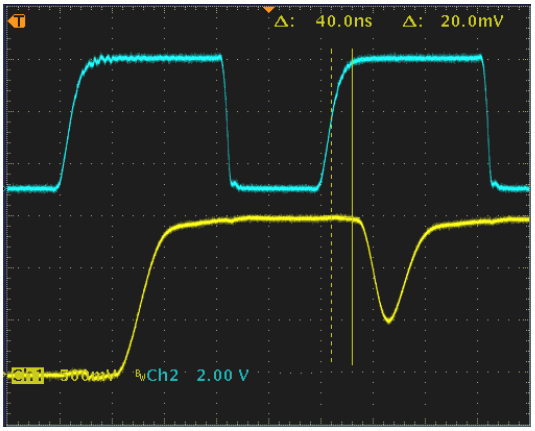

Figure 1a - TSL1401 Output Transition Time

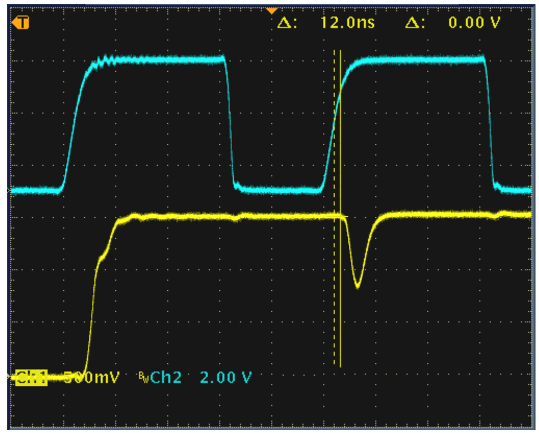

Figure 1b - TSL1401R Output Transition Time

A more subtle consequence of the faster output stage of the TSL1401R can lead to problems in some systems which sample the analog output voltage at a point near the end of the clock period. As shown in Figure 1, not only is the rise time and settling time of the TSL1401R faster, but the fall time is faster than on the TSL1401. Systems that use, for example, the rising clock edge of the subsequent clock cycle as the sample trigger of an ADC may have a problem due to the fact that the TSL1401R responds more quickly to the clock. As can be seen from the time measurements in the oscilloscope pictures of Figure 1, the TSL1401 allowed about 40ns of time after the rising clock edge of pixel (n+1)

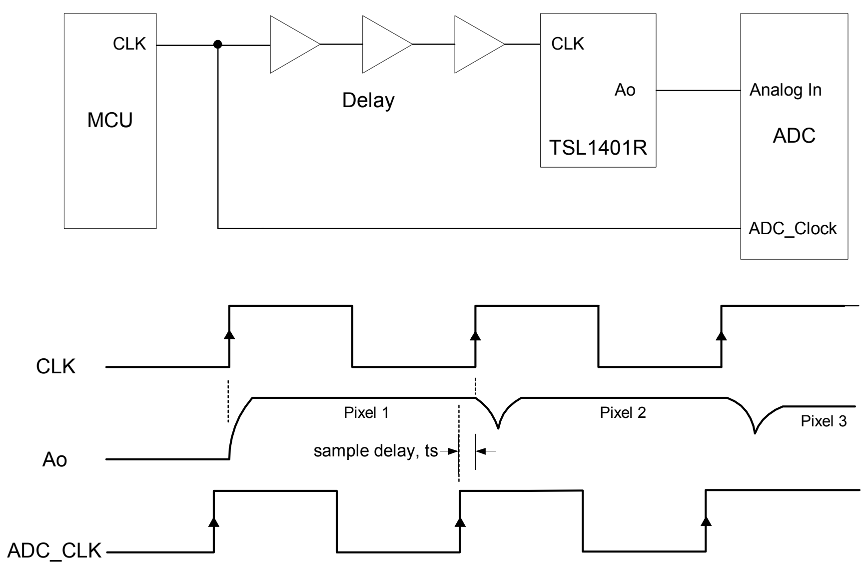

Figure 2 - Pixel Sampling Using Delayed CLK

before pixel n began to transition. The TSL1401R is about 3 times faster in this respect, allowing only 12ns or less before the pixel begins to transition after a clock edge. Generally it is best (and most conservative) to sample the pixels on the falling edge of the clock. However, in applications that demand the highest pixel rate, it will be necessary to sample closer to the end of the clock cycle. In this case, it is recommended that additional delay be added to the pixel clock as shown in Figure 2, so that the sample clock precedes the pixel clock by an amount sufficient to allow for sampling the pixel.

Supply Current
The power supply current, IDD, consumed by both devices is comparable, with the TSL1401R being slightly higher. This caused by extra quiescent current draw partly due to the higher speed amplifier circuitry. Supply current is specified as an average current draw and comes from two sources: the device circuitry and the output load. At the nominal test condition of 2V output, the load resistor accounts for 6mA during the output read cycle. So the average current is actually dependent on the amount of time spent in the pixel output cycle vs. the time spent integrating. Although the quiescent current in the TSL1401R is higher, the average current draw can be made lower by using a larger load resistor, or no resistor at all. This will reduce or eliminate the extra current through the load resistor during the output cycle.

DSNU
Dark signal non-uniformity, or DSNU, is mainly due to residual offset on the pixel integrators. This parameter has been improved on the TSL1401R. In many applications, such as black and white imaging or edge detection, DSNU is not a concern and can be neglected. However in gray-level imaging applications this should be corrected. The typical method for doing this is to first measure the pixels under dark condition, storing each value. Then when each pixel is sampled during an actual scan, the dark value for each pixel is subtracted.

Conclusion
The TSL1401R is a high performance linear sensor array that can benefit battery-operated and other systems that require high-speed operation and a wide output voltage range. With attention paid to the various differences, the TSL1401R is a pin-compatible upgrade for the TSL1401 in most systems.