

TI Space Enhanced Plastic Logic Overview and Applications in Low-Earth Orbit Satellite Platforms



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Abstract

Texas Instruments has historically only offered space-grade logic devices in larger ceramic packages, with many being released in the 1980s, 90s and early 2000s. Many of these older devices are also limited on supply voltage range, giving customers an option of either 3.3V or 5.0V V_{cc}. Rapidly emerging trends in the space industry for LEO (low-earth orbit) satellite platforms include the adoption of space-enhanced plastic (SEP) packaging over traditional ceramic packaging, as well as FPGAs (Field Programmable Gate Arrays) moving to lower supply voltages specifications such as 1.8V and even 1.2V. To best assist customers in designing next-generation space electronic systems, TI has released a brand-new group of SEP logic devices in the Space CMOS (SC) Logic family. This new family features readily available TID (total ionizing dose) + SEE (single event effects) radiation reports, 1.2V to 5.5V supply voltage support, and integrated single supply up/down level translation.

Introduction

As many modern LEO (Low-Earth Orbit) satellites are continuing to reduce in size, printed circuit board (PCB) size and power consumption limitations are rapidly becoming significant design roadblocks for many satellite system designers. Although some modern FPGAs have become smaller in size with lower voltage specifications and subsequent improvements in power efficiency, this has created additional issues. Smaller FPGAs can quickly become limited on GPIO (General Purpose Input/Output) and, more commonly, many surrounding peripheral devices remain restricted on I/O voltages, creating a so-called *voltage mismatch*. To solve these new design challenges, power-efficient and flexible interface designs are required.

A common type of interface design that has historically been sought after by satellite system designers is logic. Whether a buffer, level-translator, flip-flop, or shift register, these devices offer a reliable and cost-effective way to solve simple system design challenges and complete satellite designs. Dating back to the 1970s and 1980s, many engineers utilized Texas Instruments reliable 5V bipolar space logic devices to resolve various types of simple system design issues. While the majority of these logic devices are still available today, many of them have packages that are too large, or supply voltage specifications that are not compatible with many new FPGAs.

To both meet and exceed modern satellite system requirements, Texas Instruments performed a ground-up development on a new *Space CMOS (SC) Logic family*, integrating a number of new features and benefits.

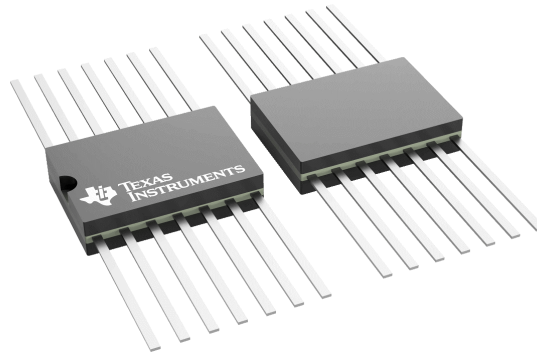


Figure 1. Bipolar Space Logic AND Gate (SN54LS08-SP) in 14-pin CFP (W) Package

Note

First released in 1983, the larger package and lead forming challenges can make it difficult to use on shorter duration, lower-cost LEO (Low-Earth Orbit) platforms

New parameters and functions - TI Space CMOS Logic Family

1. *Wide supply voltage specifications*

The SC (Space CMOS) logic family was designed to interface with many different variations of system requirements and FPGA I/O voltages. Whether running at 5V, 3.3V or even 1.2V, the SC family is able to directly interface with FPGAs of various types and run off the same supply.

Table 1. Family Comparison Table by Supply Voltage Range (Recommended Operating Conditions)

	Common Logic Product Families					
Family	AC	ACT	HC	LS	LVC	SC (New!)
Supply voltage - Min	2.0V	4.5V	2.0V	4.5V	1.65V	1.2V
Supply voltage - Max	6.0V	5.5V	6.0V	5.5V	3.6V	5.5V

2. *Integrated single supply up and down level translation*

When designing with FPGAs and lower supply voltages, one issue that many engineers encounter is known as a *voltage mismatch* between a system controller and peripheral device. For example, an FPGA can operate at a Vcc of 1.2V, while peripheral devices operate at 5V, 3.3V, or 1.8V logic levels. Especially if already using some sort of logic between these two devices, one can take advantage of the integrated level translation feature of the SCxT logic devices to solve this issue:

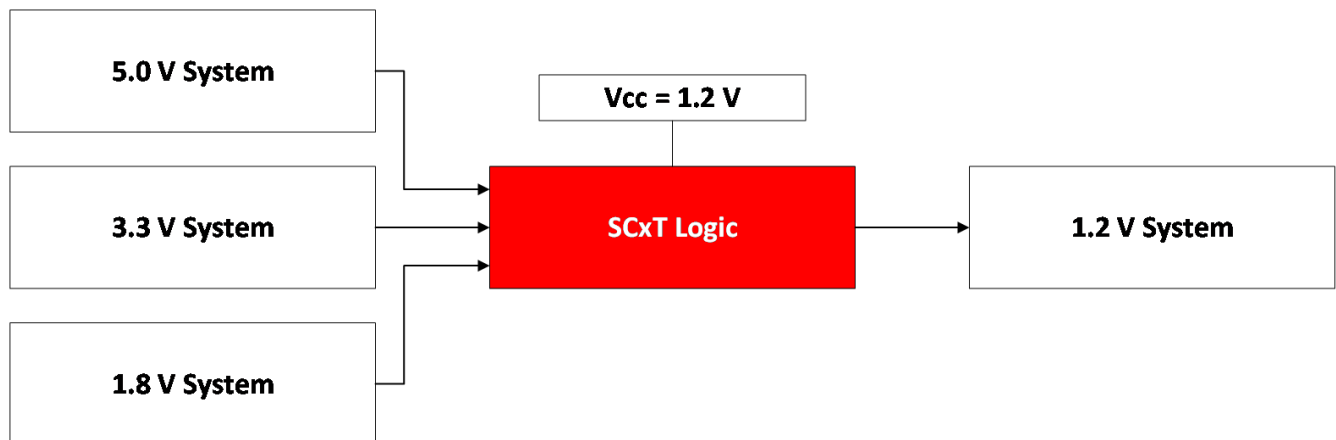


Figure 2. Visual of Single Supply Translation Feature of New Space Logic Products

3. Accessible TID (Total Ionizing Dose) and SELU (Single Event Latch-Up) reports on ti.com

The SC family was designed with radiation tolerance in mind especially at lower supply voltages like 1.2 and 1.8V (30krad, 43MeV). Radiation data reports are readily available for the SC Family Logic devices on ti.com, as well as data sheet, inventory, and other design resources.

Technical documentation

★ = Top documentation for this product selected by TI

Type	Title	
All	Filter title by keyword	<input type="text"/>
★ Data sheet	SN54SC245-SEP Radiation-Tolerant, 1.2-V to 5.5-V, Octal Bus Transceivers With 3-State Outputs datasheet	PDF HTML
★ Radiation & reliability report	SN54SC245-SEP Single Event Latch-Up Report	PDF HTML
★ Radiation & reliability report	SN54SC245-SEP Reliability Report	PDF HTML
★ Radiation & reliability report	SN54SC245-SEP Total Ionizing Dose Report	PDF HTML

Figure 3. TI.com Technical Documentation Section for Logic Space CMOS Family Devices

4. Smaller plastic packaging enables significant board area savings and weight reduction

For lower-cost LEO missions, one constraint that many system designers have to work around is a smaller PCB size. Rather than trying to trim and form the leads of a larger ceramic package, TI logic offers the space CMOS family in a much smaller, plastic TSSOP packaging.

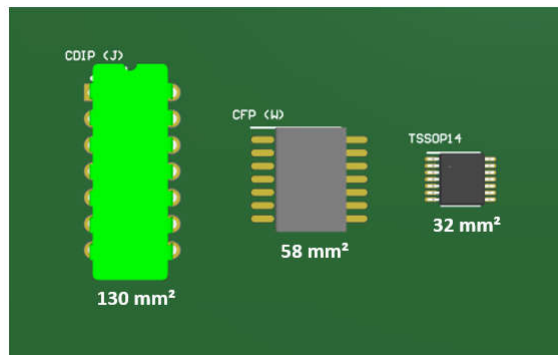


Figure 4. Area Comparison Between Two Ceramic Packages and the New Plastic Packages

5. *New pin-configurable logic functions enable increased system design flexibility*

The SN54SC3T97-SEP and the SN54SC3T98-SEP are unique devices that allow for multiple logic functions within a singular chip. Especially when looking for logic early on in a design, these devices offer quick, cost-effective, and customizable designs to common system-level design issues.

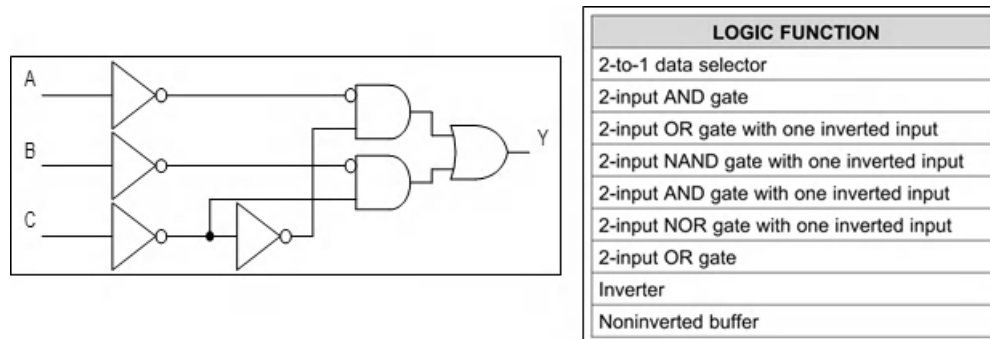


Figure 5. Logic Diagram and Function Table for 97 Function (SN54SC3T97-SEP)

6. *Integrated Triple Redundancy feature for D-type Flip-Flop (SN54SC2T74-SEP) and other sequential devices*

To best prevent SEUs (Single Event Upsets) and subsequent bit flipping, all sequential devices in the Space CMOS (SC) family such as flip-flops and shift registers come with an integrated triple modular redundancy feature. Where, each output of the sequential device is tied to a 3-channel majority voter-type circuit, and in the event of an upset of 1 channel, the 2 additional redundant paths allow the device to maintain functionality and signal integrity without failure.

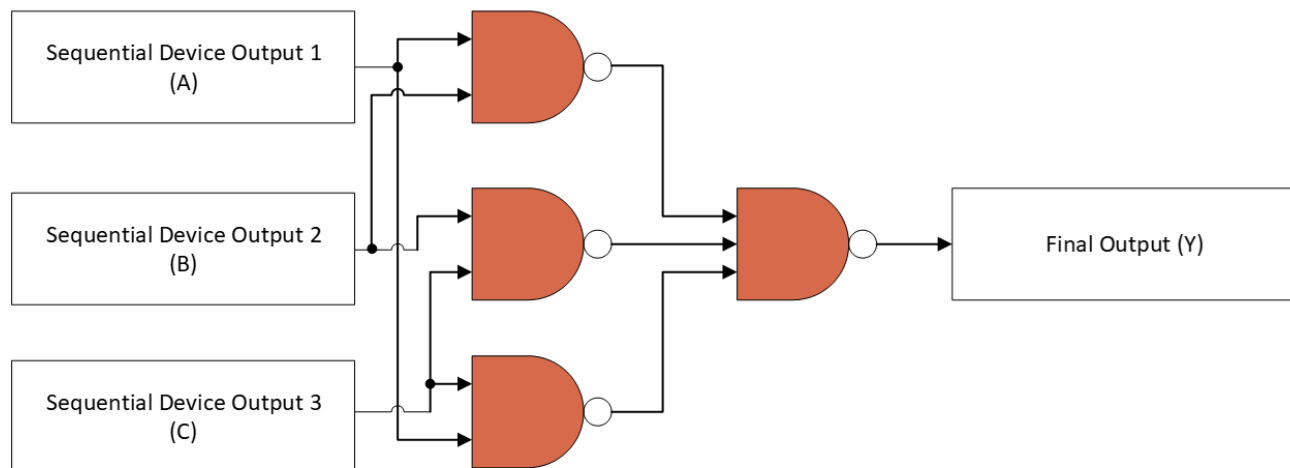


Figure 6. Triple Modular Redundancy Feature Illustration (Majority State of A/B/C = Y)

Common applications of the SC family Logic in Satellite Payloads

1. *Logic AND gates (SN54SC4T08-SEP)*

The SN54SC4T08-SEP is a 2-input, 4-channel AND gate with an integrated single-supply level translator. Many modern satellite payloads today utilize comparators to measure analog signals from various different types of sensors. Multiple logic gates are typically required to consolidate these comparator outputs and provide a single digital design to an MCU or FPGA. The added level translation feature allows for direct FPGA interface without the need for additional devices.

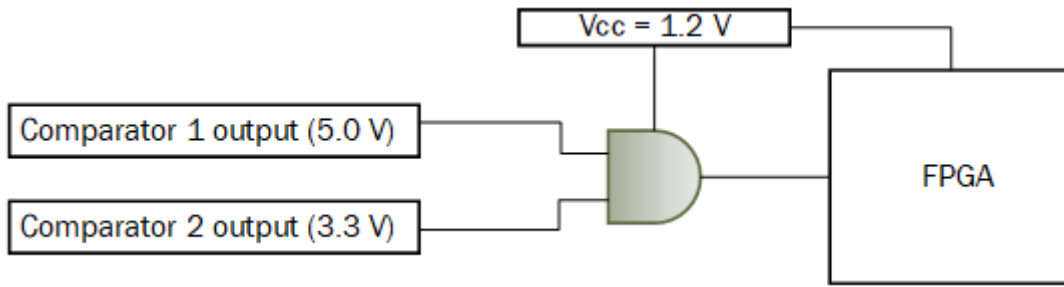


Figure 7. SN54SC4T08-SEP Comparator Consolidation Use Case

2. Octal BUS Transceiver (SN54SC245-SEP)

The SN54SC245-SEP is an Octal Bus Transceiver with 3-state outputs. With an output drive current up to 25mA, this device is excellent for driving digital signals across long board traces or transmission lines. The inputs can also accept voltages up to 5.5V, making the device capable of single supply down translation.

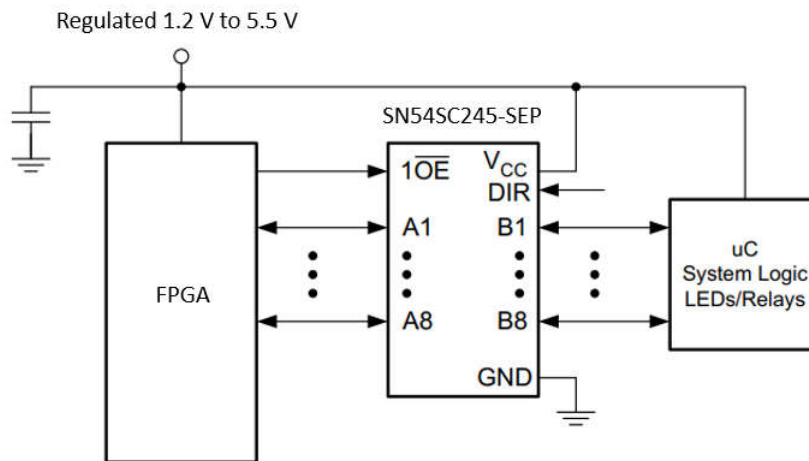


Figure 8. SN54SC245-SEP Driver Example Use Case

3. Dual-Supply Voltage Level Translator (SN54SLC8T245-SEP)

The SN54SLC8T245-SEP is a dual supply voltage level translator. This device resolves common voltage level mismatch between devices operating at the latest voltage nodes (0.7V, 0.8V, and 0.9V) and devices operating at industry standard voltage nodes (1.8V, 2.5V, and 3.3V). As modern FPGAs have moved to lower supply voltages, voltage translation type devices are becoming increasingly common in modern space systems.

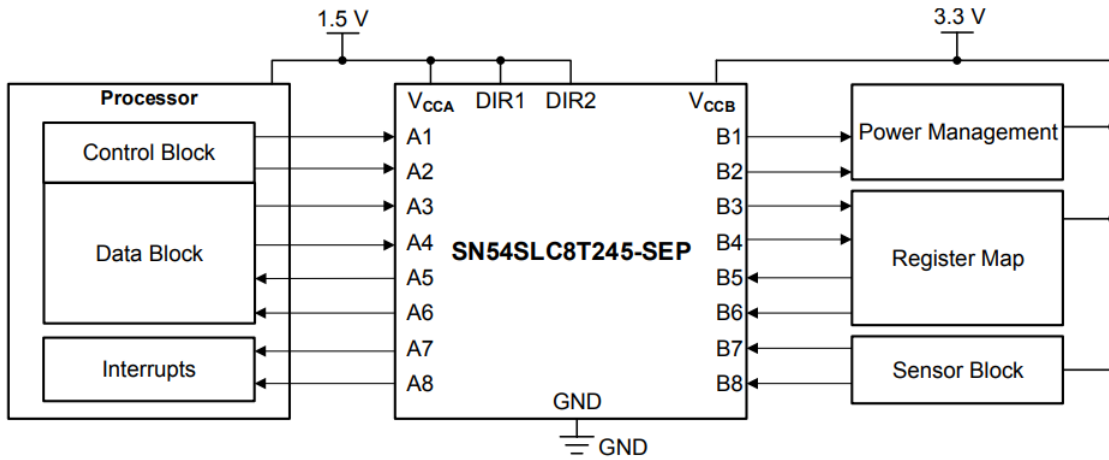


Figure 9. SN54SLC8T245-SEP Example Level Translation Use Case

Product Selection Tables

Table 2. Product Selection Tables

Logic and Voltage Translation - SEP Products					
Device	Function	Vcc	Channel #	TID and SEE ratings	Ti.com link (Data sheet, Inventory, and Radiation Reports)
SN54SC4T00-SEP	NAND Gate	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T00-SEP
SN54SC4T02-SEP	NOR Gate	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T02-SEP
SN54SC6T06-SEP	Inverter; Open-Drain	1.2V to 5.5V	6	50krad – Char. 30krad – RLAT 43MeV	SN54SC6T06-SEP
SN54SC6T07-SEP	Buffer; Open-Drain	1.2V to 5.5V	6	50krad – Char. 30krad – RLAT 43MeV	SN54SC6T07-SEP
SN54SC4T08-SEP	AND Gate	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T08-SEP
SN54SC6T14-SEP	Inverter; Schmitt-trigger	1.2V to 5.5V	6	50krad – Char. 30krad – RLAT 43MeV	SN54SC6T14-SEP
SN54SC6T17-SEP	Buffer; Schmitt-trigger	1.2V to 5.5V	6	50krad – Char. 30krad – RLAT 43MeV	SN54SC6T17-SEP
SN54SC4T32-SEP	OR Gate	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T32-SEP
SN54SC2T74-SEP	D-type Flip-Flop	1.2V to 5.5V	2	50krad – Char. 30krad – RLAT 43MeV	SN54SC2T74-SEP

Table 2. Product Selection Tables (continued)

Logic and Voltage Translation - SEP Products					
Device	Function	Vcc	Channel #	TID and SEE ratings	Ti.com link (Data sheet, Inventory, and Radiation Reports)
SN54SC4T86-SEP	XOR Gate	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T86-SEP
SN54SC3T97-SEP	Configurable multiple-function gate	1.2V to 5.5V	3	50krad – Char. 30krad – RLAT 43MeV	SN54SC3T97-SEP
SN54SC3T98-SEP	Configurable multiple-function gate; inverted	1.2V to 5.5V	3	50krad – Char. 30krad – RLAT 43MeV	SN54SC3T98-SEP
SN54SC4T125-SEP	Buffer; 3-state	1.2V to 5.5V	4	50krad – Char. 30krad – RLAT 43MeV	SN54SC4T125-SEP
SN54SC8T138-SEP	3-line to 8-line decoder/demultiplexer	1.2V to 5.5V	8	50krad – Char. 30krad – RLAT 43MeV	SN54SC8T138-SEP
SN54SC245-SEP	Octal Bus Transceiver; 3-state	1.2V to 5.5V	8	50krad – Char. 30krad – RLAT 43MeV	SN54SC245-SEP
SN54SLC8T245-SEP	Dual-Supply Voltage Translator	0.65V to 3.6V	8	20krad – Char. 20krad – RLAT 43MeV	SN54SLC8T245-SEP
SN54SC8T541-SEP	Buffer; 3-state output	1.2V to 5.5V	8	50krad – Char. 30krad – RLAT 43MeV	SN54SC8T541-SEP
SN54SC8T595-SEP	Shift Register	1.2V to 5.5V	8	50krad – Char. 30krad – RLAT 43MeV	SN54SC8T595-SEP

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