saturate
Data Word Saturator

February 1997, ver. 1 Functional Specification 6

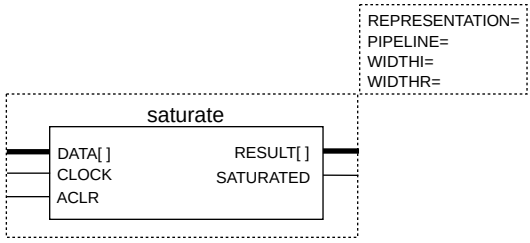
Features

- saturate reference design implementing a data word saturator
- Optimized for FLEX® 10K and FLEX 8000 device architectures
- Saturates data words to prevent roll over
- Parameterized input width, output width, and pipeline levels
- Supported by MAX+PLUS® II software
- Signed (two's complement) or unsigned operations
- Pipelined or non-pipelined operation
- Useful for a variety of applications, including communications, finite impulse response (FIR) filters, image processing, video processing, and signal processing

General Description

The saturate reference design is an ideal solution for digital signal processing (DSP) systems, where data word length and growth are important design aspects. For example, because internal data processing often results in more data bits than is desired for the output, the number of significant bits must be decreased. The saturate reference design provides an efficient technique to decrease the number of significant bits. Figure 1 shows the symbol for the saturate reference design.

Figure 1. saturate Symbol



Function Prototype

The Altera® Hardware Description Language (AHDL) Function Prototype of the saturate reference design is shown below:

```
FUNCTION saturate (data[WIDTHI-1..0], clock, aclr)
  RETURNS (result[WIDTHR-1..0], saturated);
```

Parameters

Table 1 describes the parameters of the saturate reference design.

Table 1. saturate Parameters

Name	Value	Description
REPRESENTATION	"SIGNED" (two's complement) or "UNSIGNED"	Representation of the input data; the default value is "UNSIGNED".
PIPELINE	Integers only	Number of pipeline stages in the saturator. Two is the maximum useful value.
WIDTHI	Integers only	Width of input data.
WIDTHR	Integers only	Width of output data.

Ports

Table 2 describes the input and output ports of the saturate reference design.

Table 2. saturate Ports

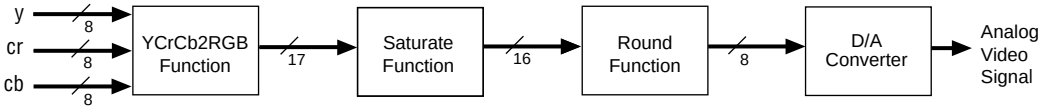
Name	Type	Description
data[WIDTHI–1..0]	Input	Input data.
clock	Input	Clock input. Used only if PIPELINE is greater than 0.
aclr	Input	Asynchronous clear; used only if PIPELINE greater than 0.
result[WIDTHR–1..0]	Output	Saturated output data.
saturated	Output	Logic high if saturation has occurred; logic low if saturation has not occurred.

Functional Description

The saturate function provides either signed or unsigned operation. For signed operation, when the input signal rises above $2^{WIDTHR-1}-1$, the output value is saturated to $2^{WIDTHR-1}-1$, or if the input signal goes below $-2^{WIDTHR-1}$, the output is saturated to $-2^{WIDTHR-1}$. For unsigned operation, when the input signal rises above $2^{WIDTHR}-1$, the output value is saturated to $2^{WIDTHR}-1$.

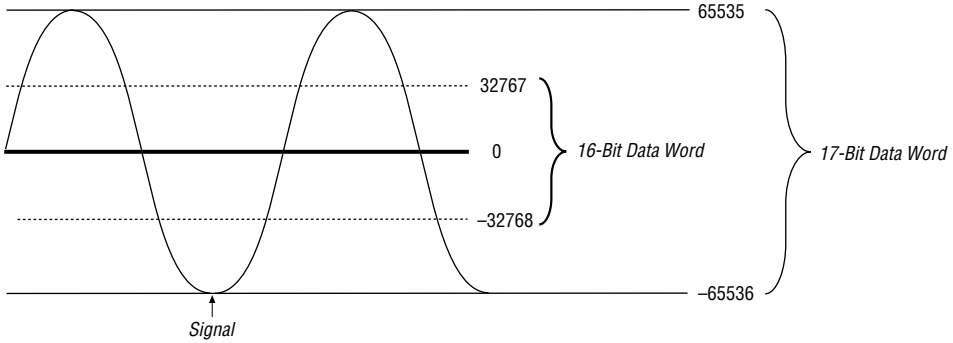
Figure 2 is a simplified illustration of an 8-bit color channel in a digital video system. In this example, color space conversion is performed using the YCrCb2RGB function. Depending on the input values to the YCrCb2RGB function, the multiplication used in the color conversion may result in a 17-bit data word that rolls over. (For an example of data word roll over, see Figure 4.) To avoid data word roll over, this 17-bit digital video signal is fed to the saturate function, where it is saturated to a 16-bit word. The signal is then fed to the round function, where it is rounded to an 8-bit word. At this point, the data word is ready for conversion to an analog video signal.

Figure 2. Digital Video Channel



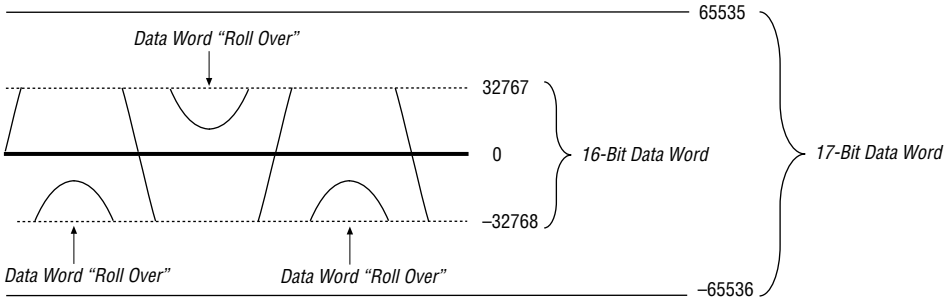
The following figures show examples of the 17-bit digital video signal, using signed representation, as it is processed down to an 16-bit signal. Figure 3 shows the sine wave of the signal before saturation.

Figure 3. Sine Wave of 17-Bit Data Word



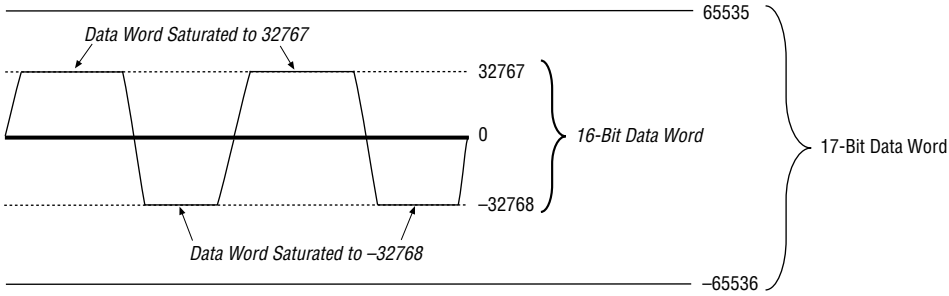
If a technique is not used to decrease the number of significant bits, data word roll over will occur. Figure 4 shows the effect on the signal as the data word rolls over, i.e., as the signal passes 32767, it shifts from positive full-scale operation to negative full-scale operation, and vice versa as it passes –32768. The output of this example can be catastrophic in many systems.

Figure 4. Sine Wave with Data Word "Roll Over"



To avoid data word roll over, the data is saturated Figure 5 shows the signal after the data word is saturated; all values above 32767 become 32767, and all values below –32768 become –32768.

Figure 5. Sine Wave of Saturated Data Word



For information on rounding, refer to *Functional Specification 5 (round Data Word Rounder)*, for information on color space conversion, refer to *RGB2YCrCb & YCrCb2RGB Color Space Converters Data Sheet*.

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