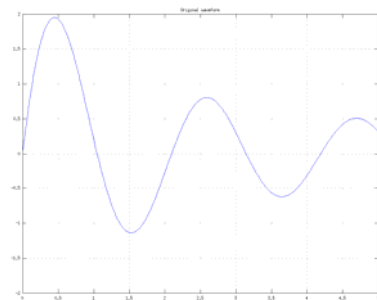


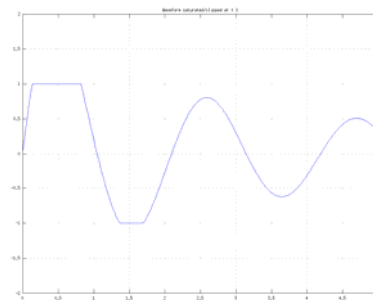
SATURATION

Saturation (or Clipping)

- Eliminates MSB bits
- Common to saturate a signal after an operation which will or *may* cause the magnitude of a signal to increase



Original waveform



Saturated/clipped waveform

Saturation (or Clipping)

- Matlab code that produced previous example waveforms

```

% Example saturated/clipped waveform
% 2009/02/03 Written

SatHi = 1.0;
SatLo = -1.0;
stepsize = 0.01;
a = 0 : stepsize : 5;
index = (a + stepsize) * (1/stepsize); % matlab indexes start at 1 :-(
index = round(index); % clear out VERY small offsets

b = 2.9 * sin(a*3) ./ (a+1); % constants chosen to look nice

% plot original waveform
figure(1);clf;
plot(a,b);
grid on;
axis([0 5 -2 +2]);
title('Original waveform');

%print -dtiff 1.tiff % 75 KB
print -dpng 1.png % 16 KB, both look equally sharp

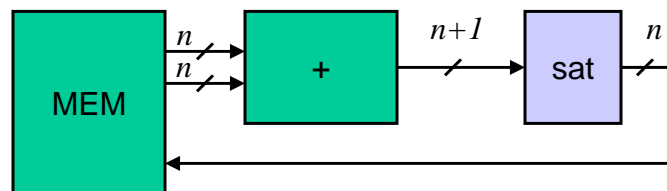
% saturate/clip original waveform
for l = index,
    if b(l) > SatHi
        c(l) = SatHi;
    elseif b(l) < SatLo
        c(l) = SatLo;
    else
        c(l) = b(l);
    end
end

% plot saturated waveform
figure(2);clf;
plot(a,c);
grid on;
axis([0 5 -2 +2]);
title('Waveform saturated/clipped at \pm 1');

%print -dtiff 2.tiff % 75 KB
print -dpng 2.png % 16 KB, both look equally sharp
    
```

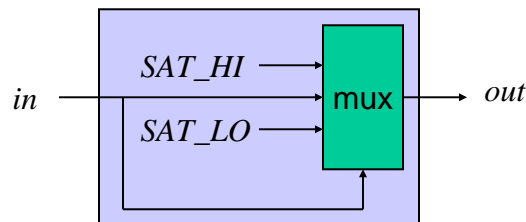
Saturation (or Clipping)

- Normally accompanied by a reduction in the word width
- Preserves precision of a fixed-width number representation



Saturation (Clipping)

- Basically check for 3 possibilities
 - $in > SAT_HI$
 - $in < SAT_LO$
 - else
- Think of saturator as a three-input mux



0111 SAT_HI
 0110 SAT_HI
 0101 SAT_HI
 0100 SAT_HI
0011 either
 0010 in
 0001 in
 0000 in
 1111 in
 1110 in
 1101 in
1100 either
 1011 SAT_LO
 1010 SAT_LO
 1001 SAT_LO
 1000 SAT_LO

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Saturation (Clipping)

- Look for when MSB and MSB-1 bits are different. When they are different, the MSB can not be dropped and the output must be saturated.
 - `if (in[MSB:MSB-1] == 2'b01)`
 - `if (in[MSB:MSB-1] == 2'b10)`
 - `out = in[MSB-1:0];`
- Similar approach to saturate more than one bit
 - To saturate $S-1$ bits, look for when the S MSB bits are not all the same value

0111 SAT_HI
 0110 SAT_HI
 0101 SAT_HI
 0100 SAT_HI
0011 either
 0010 in
 0001 in
 0000 in
 1111 in
 1110 in
 1101 in
1100 either
 1011 SAT_LO
 1010 SAT_LO
 1001 SAT_LO
 1000 SAT_LO

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Saturation Bias Effects

- Usually clip to: (+) 01111...111
(-) 10000...000
- But this gives a non-zero mean
- This may cause problems
 - Very sensitive circuits; e.g., a signal path containing an accumulator
 - Worse for small-width words
- Sensitive circuits may require clipping to:
(+) 01111...111
(-) 10000...001
 - The SAT_LO comparison is now more complex: the saturation detection circuit in the critical path must now look at all bits in the input word