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

```matlab
% 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 -djpeg 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 -djpeg 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
  - \( \text{in} > \text{SAT_HI} \)
  - \( \text{in} < \text{SAT_LO} \)
  - else

- Think of saturator as a three-input mux

\[
\begin{array}{c}
\text{in} \\
\text{SAT_HI} \\
\text{SAT_LO} \\
\text{mux} \\
\text{out}
\end{array}
\]

- if (in[MSB:MSB-1] == 2'b01)
- if (in[MSB:MSB-1] == 2'b10)
- else

- 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
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