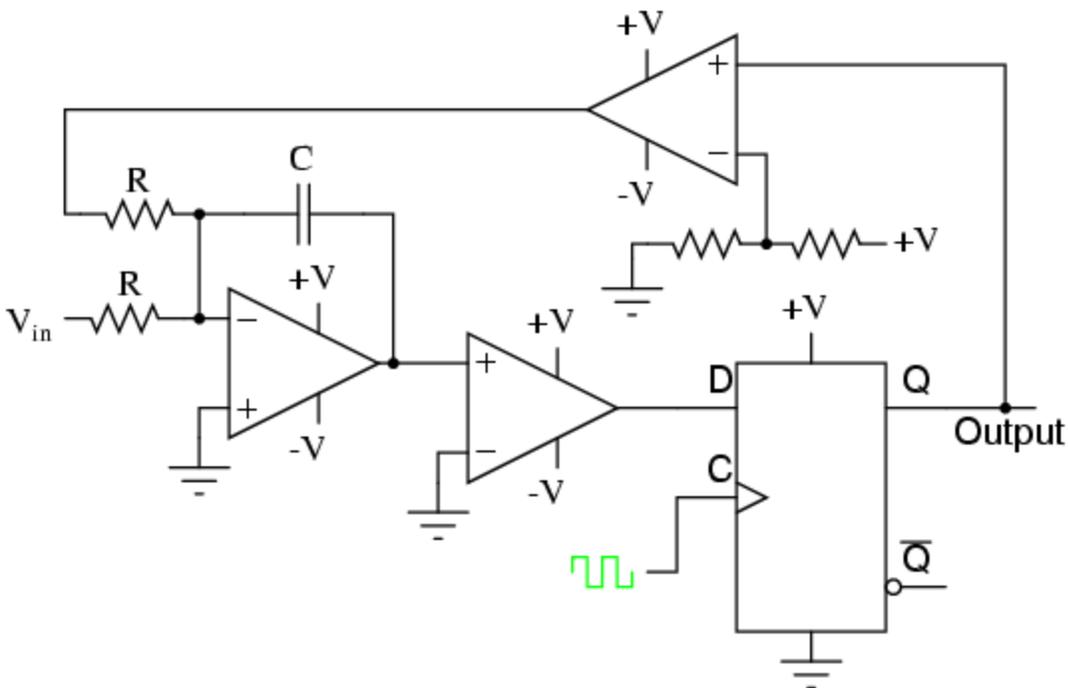


Delta Sigma ADC

One of the more advanced ADC technologies is the so-called delta-sigma, or $\Delta\Sigma$ (using the proper Greek letter notation). In mathematics and physics, the capital Greek letter delta (Δ) represents *difference* or *change*, while the capital letter sigma (Σ) represents *summation*: the adding of multiple terms together. Sometimes this converter is referred to by the same Greek letters in reverse order: sigma-delta, or $\Sigma\Delta$.

In a $\Delta\Sigma$ converter, the analog input voltage signal is connected to the input of an integrator, producing a voltage rate-of-change, or slope, at the output corresponding to input magnitude. This ramping voltage is then compared against ground potential (0 volts) by a comparator. The comparator acts as a sort of 1-bit ADC, producing 1 bit of output ("high" or "low") depending on whether the integrator output is positive or negative. The comparator's output is then latched through a D-type flip-flop clocked at a high frequency, and *fed back* to another input channel on the integrator, to drive the integrator in the direction of a 0 volt output. The basic circuit looks like this:



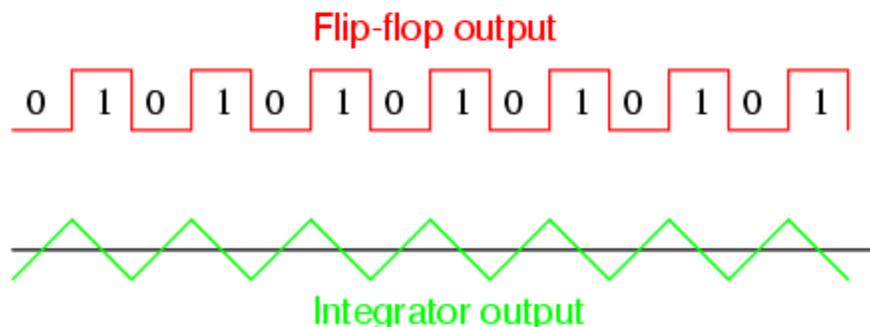
The leftmost op-amp is the (summing) integrator. The next op-amp the integrator feeds into is the comparator, or 1-bit ADC. Next comes the D-type flip-flop, which

latches the comparator's output at every clock pulse, sending either a "high" or "low" signal to the next comparator at the top of the circuit. This final comparator is necessary to convert the single-polarity 0V / 5V logic level output voltage of the flip-flop into a +V / -V voltage signal to be fed back to the integrator.

If the integrator output is positive, the first comparator will output a "high" signal to the D input of the flip-flop. At the next clock pulse, this "high" signal will be output from the Q line into the noninverting input of the last comparator. This last comparator, seeing an input voltage greater than the threshold voltage of $1/2 +V$, saturates in a positive direction, sending a full +V signal to the other input of the integrator. This +V feedback signal tends to drive the integrator output in a negative direction. If that output voltage ever becomes negative, the feedback loop will send a corrective signal (-V) back around to the top input of the integrator to drive it in a positive direction. This is the delta-sigma concept in action: the first comparator senses a *difference* (Δ) between the integrator output and zero volts. The integrator *sums* (Σ) the comparator's output with the analog input signal.

Functionally, this results in a serial stream of bits output by the flip-flop. If the analog input is zero volts, the integrator will have no tendency to ramp either positive or negative, except in response to the feedback voltage. In this scenario, the flip-flop output will continually oscillate between "high" and "low," as the feedback system "hunts" back and forth, trying to maintain the integrator output at zero volts:

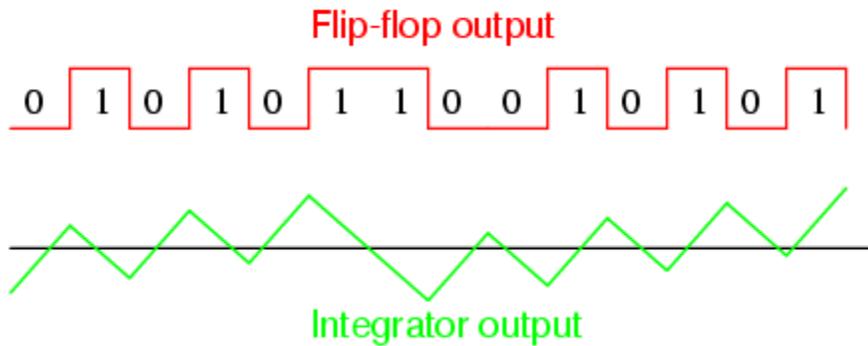
*$\Delta\Sigma$ converter operation with
0 volt analog input*



If, however, we apply a negative analog input voltage, the integrator will have a tendency to ramp its output in a positive direction. Feedback can only add to the

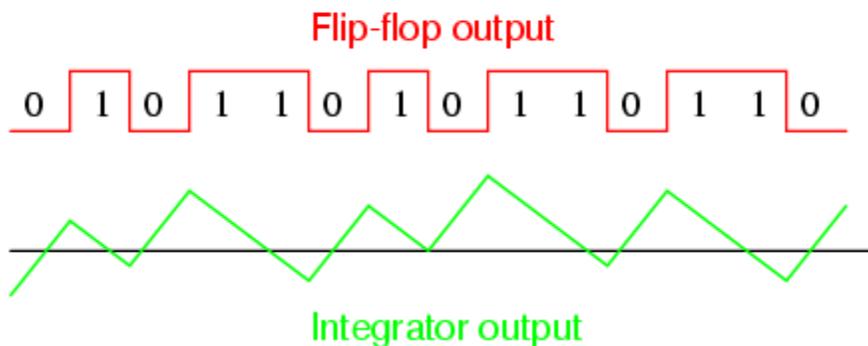
integrator's ramping by a fixed voltage over a fixed time, and so the bit stream output by the flip-flop will not be quite the same:

$\Delta\Sigma$ converter operation with small negative analog input



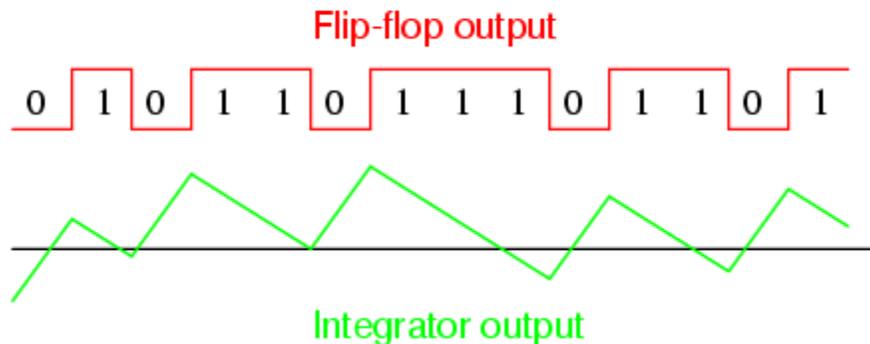
By applying a larger (negative) analog input signal to the integrator, we force its output to ramp more steeply in the positive direction. Thus, the feedback system has to output more 1's than before to bring the integrator output back to zero volts:

$\Delta\Sigma$ converter operation with medium negative analog input



As the analog input signal increases in magnitude, so does the occurrence of 1's in the digital output of the flip-flop:

*$\Delta\Sigma$ converter operation with
large negative analog input*



A parallel binary number output is obtained from this circuit by averaging the serial stream of bits together. For example, a counter circuit could be designed to collect the total number of 1's output by the flip-flop in a given number of clock pulses. This count would then be indicative of the analog input voltage.

Variations on this theme exist, employing multiple integrator stages and/or comparator circuits outputting more than 1 bit, but one concept common to all $\Delta\Sigma$ converters is that of *oversampling*. Oversampling is when multiple samples of an analog signal are taken by an ADC (in this case, a 1-bit ADC), and those digitized samples are averaged. The end result is an effective increase in the number of bits resolved from the signal. In other words, an oversampled 1-bit ADC can do the same job as an 8-bit ADC with one-time sampling, albeit at a slower rate.

Source: http://www.allaboutcircuits.com/vol_4/chpt_13/9.html