

Many experiments & technologies involve counting

Have seen how to make counter from flip-flops

= basic state machine

Easier to use dedicated IC

Typical features:

- Count up & down
- Easy to cascade multiple chips
- Load arb. starting values

Usually very convenient

Related issue: how to generate clock signals?

Need oscillator

Oscillator Types:

- RC: based on time for capacitor to charge/discharge  
relative accuracy  $\sim 10^{-3}$ , limited by drift  
in R with temperature
- LC: based on resonant freq of LC circuit  
accuracy  $\sim 10^{-4}$ , limited by component drift & aging
- Crystal: based on mechanical resonance of piezoelectric crystal  
accuracy  $\sim 10^{-6}$   
temperature stabilized  $\sim 10^{-10}$
- Atomic clock: frequency of atomic transitions  
accuracy  $\sim 10^{-12}$
- GPS signal: atomic clocks in space!  
accuracy  $\sim 10^{-12}$

• Time standard: fancy laboratory based atomic clock  
accuracy  $\sim 10^{-16}$   
Used to realize definition of second (Cs transition)  
defines UTC

• Optical clock: atomic clock based on optical transition,  
very precise lasers  
accuracy  $10^{-18}$ ?

Note age of universe is  $\sim 4 \times 10^{17}$  s (13.8 years)

Optical clock would measure to  $\sim 1$  s accuracy

Older standards:

Pendulum clock (best ever):  $10^{-8}$

Earth rotation:  $10^{-8}$