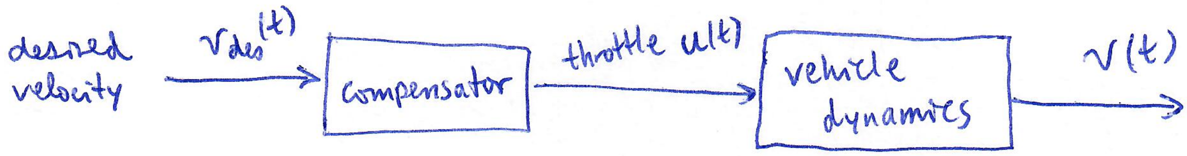
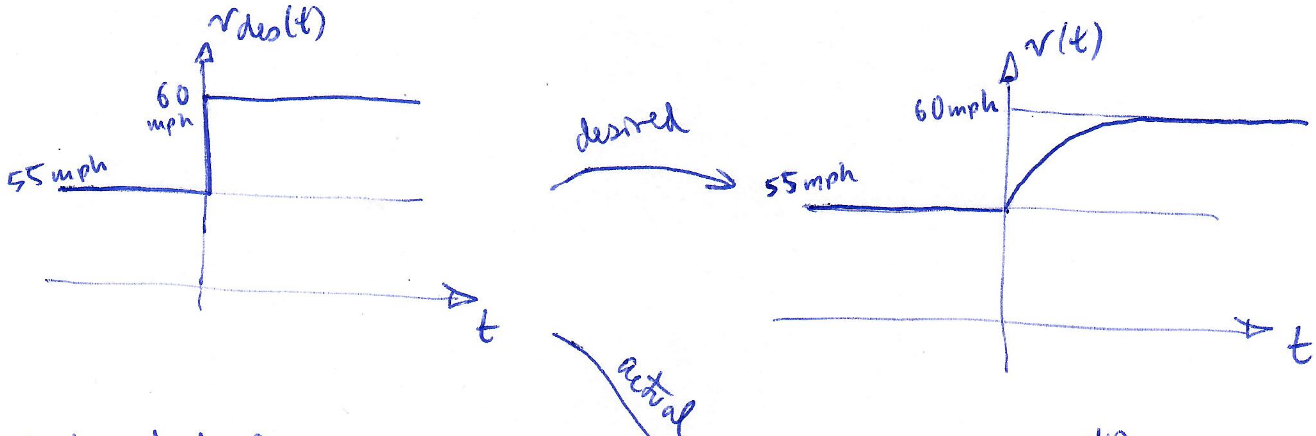
ME 4555 - Lecture 21 - Feedback

The typical scenario is that we have a system whose dynamics are slow or otherwise undesirable, and we want to use feedback to <u>modify</u> those dynamics.

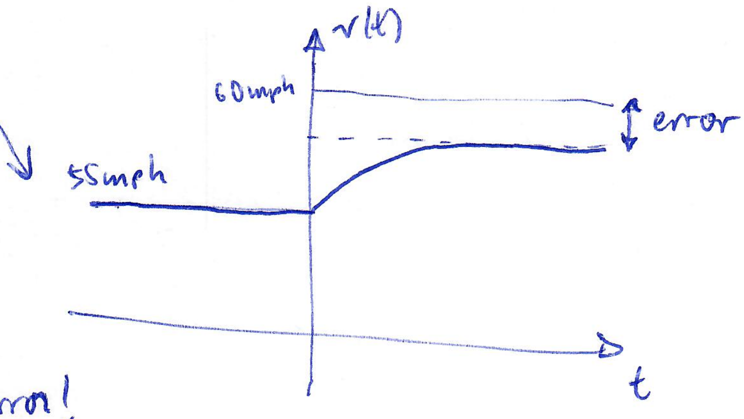
<u>Ex</u>: cruise control. If we use no feedback (open-loop design) we get an architecture like:



The compensator converts a velocity into a throttle amount (how much the pedal is pressed). What we expect:



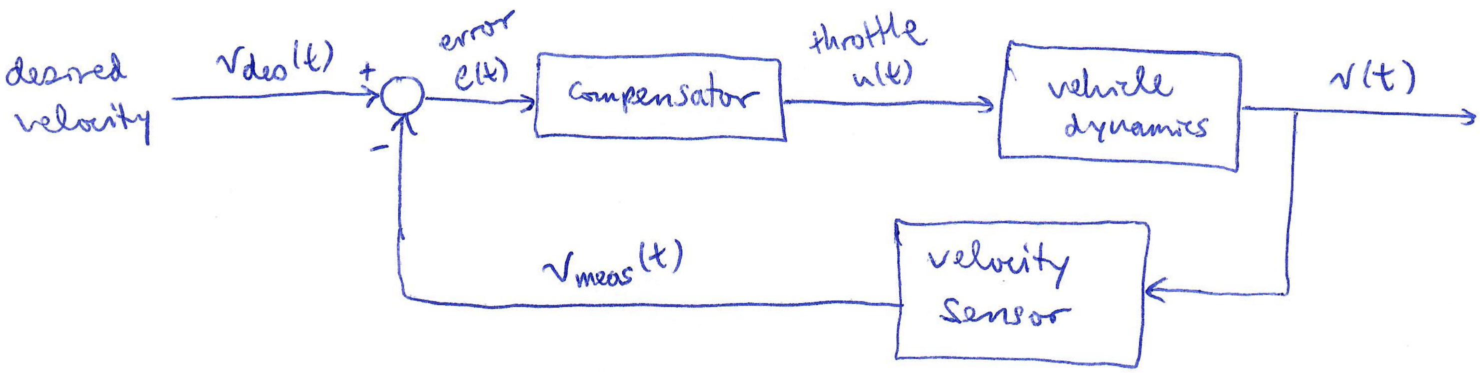
but what if we were on a hill? and we need more throttle to get to 60mph?



this open-loop control strategy will produce a steady-state error!

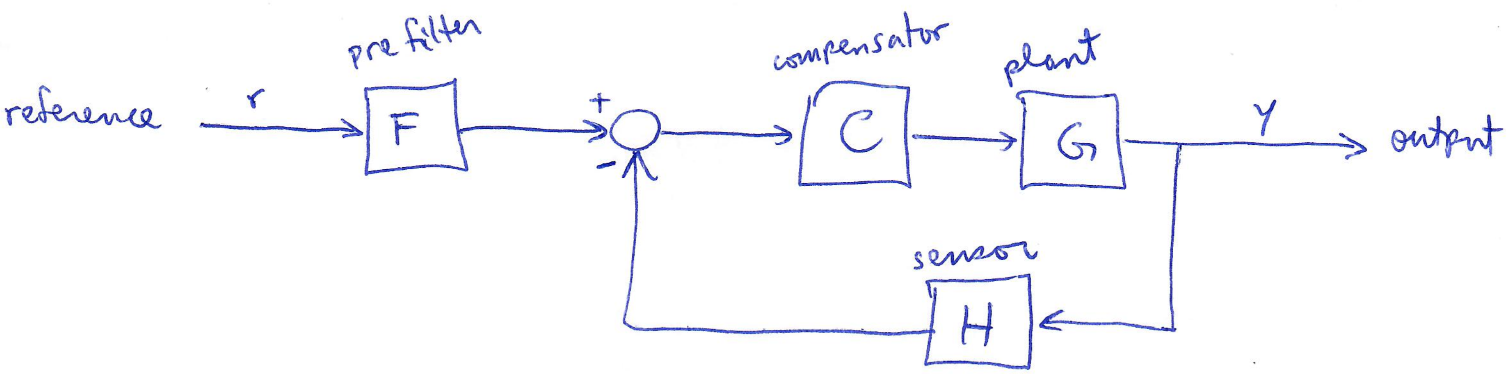
Ex cruise control (cont'd)

solution: use feedback!



The compensator acts on the error ($v_{des}(t) - v(t)$). In general, the compensator and sensor can have their own dynamics.

Here is a general architecture for the tracking problem:

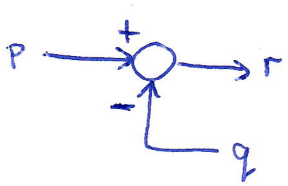


★ The compensator C is sometimes called the "controller". Sometimes "K" instead.

★ The prefilter F is sometimes called the "feed forward" term. It can also be placed after the feedback loop.

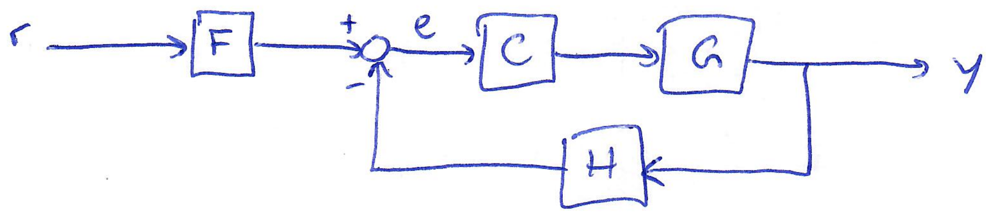
★ The "feedforward path" is "$F \to C \to G$".

★ The signs next to the junction indicate addition or subtraction.



means $r = p - q$.

We can combine the transfer functions into a single transfer function as follows:



error signal: $e = Fr - Hy$

feedforward path: $y = GCe$

$y = GC(Fr - Hy)$

$\Rightarrow \; y = GCFr - GCHy$

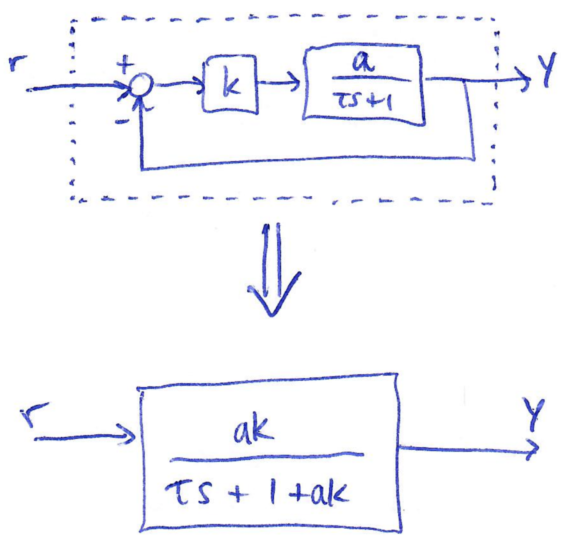
$$\Rightarrow \; \boxed{y = \left(\frac{GCF}{1 + GCH}\right) r}$$

this is called the "closed-loop map" from r to y.

Example: Let $F = H = 1$ (no pre-filter or sensor dynamics).

Let $C = k$ (this is called a proportional controller. The response is proportional to the error).

Let $G = \dfrac{a}{\tau s + 1}$ (first order system).



$$\frac{GC}{1 + GC} = \frac{\frac{ak}{\tau s + 1}}{1 + \frac{ak}{\tau s + 1}} = \frac{ak}{\tau s + 1 + ak}$$

New system: (closed loop) $\dfrac{ak/(1+ak)}{(\tau/(1+ak))s + 1}$

New gain: $\dfrac{ak}{ak + 1}$

New time constant: $\dfrac{\tau}{1 + ak}$

So the original system has gain a, time const. τ.

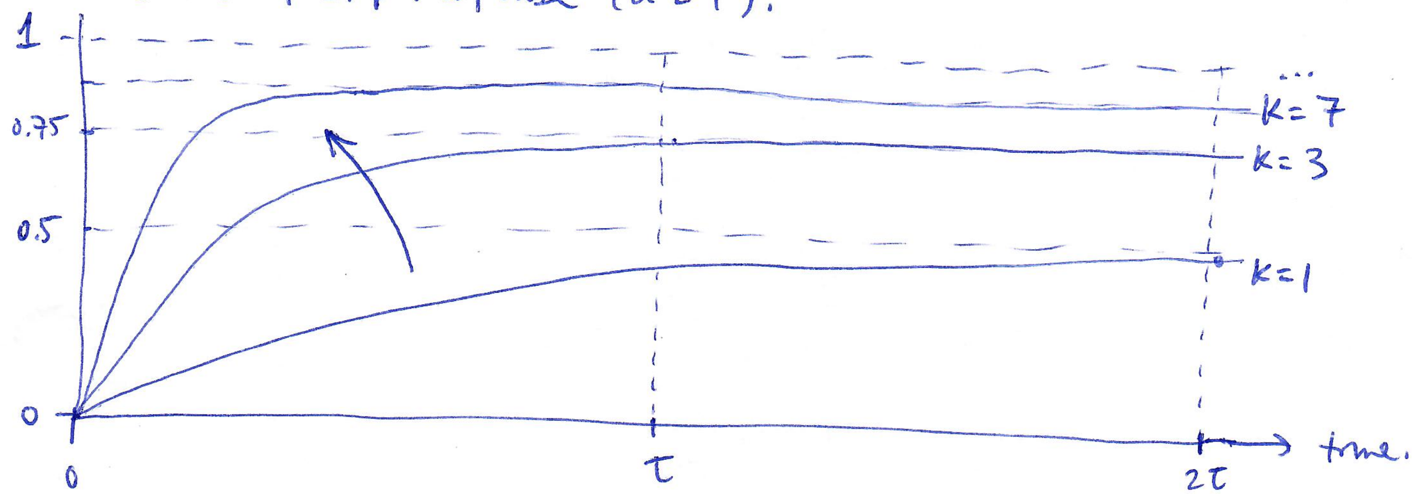
The new system has gain $\frac{ak}{ak+1}$, time const. $\frac{\tau}{ak+1}$.

As k gets <u>larger</u>, τ gets <u>smaller</u> (faster response).

Also, our gain is always less than 1: $\frac{ak}{ak+1} < 1$.

As k gets larger, we can make the gain closer to 1.

Closed-loop step response $(a=1)$.



What if we want no error at all (gain of 1)? This isn't possible if we use only proportional control. Two options:

★ use feedforward $F = \frac{ak+1}{ak}$ to cancel out the $\frac{ak}{ak+1}$ gain.

<u>Problem</u>: same as open-loop control! if our plant has a bit of uncertainty, e.g. we aren't exactly sure about the value of a, then we can't know how to pick F.

★ use "integral action" (more on this later!)