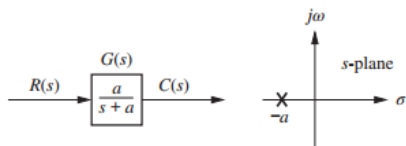


- The next step following block reduction — **analysis and design**
- **Make analysis** to see if the response specification and performance requirements can be met by simple adjustment of system parameters
 - **If not** — design additional hardware controllers
 - one of the most important analysis technique is **time-domain analysis**
- Test signals
 - Engineer usually selects **standard test inputs**
 - Impulse
 - Step
 - Ramp
 - Parabolic
 - Sinusoid
 - Which one of these typical input signals to use?
 - determined by the form of the input that the system will be subjected
 - Gradually changing functions of time — **ramp**
 - sudden disturbances — **Step**
 - shock inputs — **Impulse**
- Step input
 - Represent constant command such as position, velocity, or acceleration

- if the system's output is position, the step input represents a desired position
- If the system's output is velocity, the step input represents a constant desired speed
- Ramp input
 - Represents a linearly increasing command
 - if the system's output is position, the input ramp represents a linearly increasing position, such as that found when tracking a satellite moving across the sky at constant speed
- Once a control system is **designed on the basis of test signals**, the **performance** of the system in response to **actual inputs** is **generally satisfactory**
 - **enables one to compare the performance of many systems** on the same basis
- Control system behavior is altered by **fluctuations** in component values or system parameters — caused by **temperature, pressure**, or other **environmental changes**
- the designer is concerned about **transient response, steady-state error, stability**, and **sensitivity**
- Transient response of 1st-order system
 - relationship between the input and the output **involves the rate at which the output changes**

- contains storage element cannot respond instantaneously to change an input
 - **mercury in glass thermometer**
 - **Velocity of a true falling mass**
 - Air pressure build-up in **bellow**
- thermometer at temperature T_0 inserted into a liquid at a temperature
- how the output, i.e. the reading of the thermometer T , varies with time

$$T(t) = T_1 + (T_0 - T_1)e^{-t/\tau}$$
- **Time constant**
 - time the system takes to reach 63.2% of its final value
 - **1 τ : 63%**
 - **2 τ : 86%**
 - **3 τ : 95%**
- The system response is called a “**first-order lag**” because the **output lags behind the input**
- The dynamic shape of 1st-order response to a step input is a function of time constant



- Location of pole — time constant

- farther the pole from the imaginary axis, the faster the transient response
- Rise time
 - The time for the waveform to go from 0.1 to 0.9 of its final value
 - $T_r = \frac{2.2}{a}$
- Settling time
 - time for the response to reach, and stay within, 2% of its final value
 - $T_s = \frac{4}{a}$
- 1st-order transfer function via testing

$$C(s) = \frac{K}{s(s+a)} = \frac{K/a}{s} - \frac{K/a}{s+a}$$

- identify ***K*** and ***a*** from laboratory testing, we can obtain the transfer function of the system
 - **has the first-order characteristics — no overshoot and nonzero initial slope**
- Response of 1st-order system to ramp input

$$C(s) = \frac{1}{s^2} * \frac{1}{\tau s + 1}$$

$$c(t) = t - \tau + \tau e^{-t/\tau}$$

$$e(\infty) = \tau$$

- The smaller the time constant τ , the smaller the steady-state error in following the ramp input