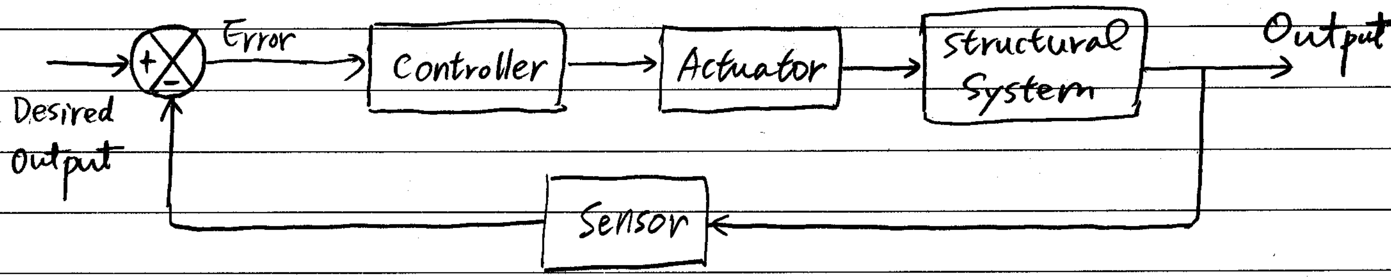


Block diagram of the adaptive structure control system

- Transducers : energy-conversion devices
  include sensors and actuators
  - sensors : acquire information from the system
  - actuators: output actions into the system
  - smart actuators and sensors : actuators and sensors with the use of smart materials

- Major defects in primary sensors :
  - nonlinearity
  - cross-sensitivity
  - noise
  - parameter drift

Some techniques for compensating the defects:

- linearization processes are realizable with digital electronics
- the material forming the sensor is physically organized to maximize the sensitivity of the device to the target variable and to minimize the response to all other physical variables
- use sensor array approach

e.g. chemiresistors

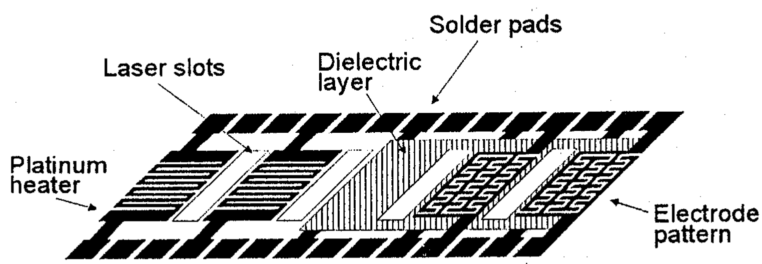


Fig. 7.2. An example of an array of chemiresistors fabricated using thick–film techniques. The slots are cut by a laser and help to isolate each sensor site from its neighbors

- use filters (analog or digital)
- positioning is critical
- the entire compensation and communications system can be constructed in single-chip form
- prefer self-test and auto-calibration features

- Actuators:
  - output quantity is an energy or power,
  - often in the form of mechanical work
  - input of the actuator is driven electrically whenever possible
  - connected in series with a power provider (power amplifier)
  - considerations:
    required control authority (amount of control force, moment, strain or displacement, etc.)
    power consumption, frequency response, and physical constraints such as size and mounting requirements, etc.

- Smart Actuators:
  - solid-state actuators: piezoelectric actuators, shape memory actuators, magnetostrictive actuators
  - actuators with controllable fluids (smart fluids):
    magnetorheological fluid actuators,
    electrorheological fluid actuators

Transduction Devices for Adaptive Structures

- Accelerometer (sensor)
- Electrodynamic shaker (actuator)
- Electrorheological fluid (actuator)
- Electrostrictive material (actuator)
- Magnetorheological fluid (actuator)
- Magnetostrictive material (actuator)
- Optical fibers (sensor)
- Piezoelectric material (actuator or sensor)
- Shape memory alloy (actuator or sensor)
- Strain gauge (sensor)

- Piezoelectric Actuators / Sensors

Constitutive eqs :

$$\begin{cases} D = dT + \varepsilon^T E & (1) \\ S = s^E T + d^t E & (2) \end{cases}$$

or $$\begin{cases} E = -gT + \beta^T D & (3) \\ S = s^D T + g^t D & (4) \end{cases}$$

where g piezoelectric constants

β^T impermittivity constants for constant T

s^D elasticity matrix for constant D

From eq (2),

induced strain $\boxed{S_j = d_{ij} E_i}$ (a)

From eq. (1),

when $E=0$ (short circuit)

$$D_i = d_{ij} T_j \qquad (b)$$

the "strain" constants d

- a measure of the strain produced by an applied electric field (The Motor Effect)

- a measure of the short circuit charge density to the applied stress (The Generator Effect)

From eq. (3),

when $D=0$ (open circuit)

$$\boxed{E_i = -g_{ij} T_j} \qquad (c)$$

The "voltage" constants g

- a measure of the electric field (open circuit) by an applied mechanical stress.

From eq. (4),

induced strain $S_j = g_{ij} D_i$ (d)

From (a) - (d).

$$d = \frac{\text{strain developed}}{\text{applied electric field}}$$

$$= \frac{\text{short circuit charge density}}{\text{applied mechanical stress}}$$

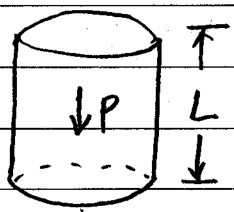
$$g = \frac{\text{open circuit electric field}}{\text{applied mechanical stress}}$$

$$= \frac{\text{strain developed}}{\text{applied charge density}}$$

* Actuators need high "strain" constants d

* Sensors need high "voltage" constants g

e.g.



$L = 20\ mm$, $A = 1\ cm^2$

$g_{33} = 24 \times 10^{-3}\ V \cdot m/N$

$d_{33} = 390 \times 10^{-12}\ m/V$

Voltage - force relationship

$V = EL$ and $T = \frac{F}{A}$

$E = -g_{33} T \Rightarrow$

$$V = -g_{33} \frac{L}{A} F$$

for $F = -20N \Rightarrow V = 96\ V$

Displacement - voltage relation,

$S = d_{33} E = d_{33} \frac{V}{L} = \frac{\Delta L}{L}$

$\Rightarrow \Delta L = d_{33} V$

for $10\ kV$ or $E = 500\ V/mm \Rightarrow \Delta L = 3.9\ \mu m$