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Manufacturing and trimming of a low-cost industrial thick-film force sensor

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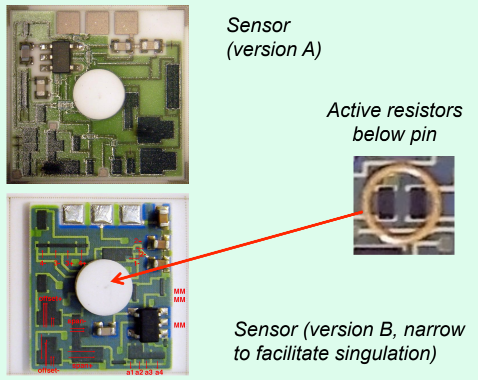
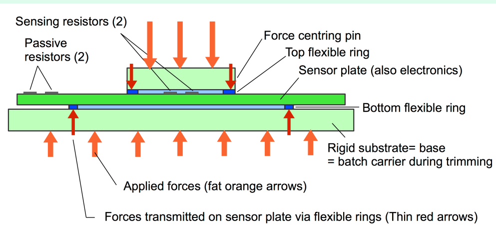
Sensor & sensing principle

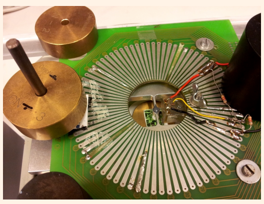




Manufacturing

Design for production

- All-in-one, all electrical signals in one side of thick-film sensing body, with mechanical base & force-centring pin
- Mounted on base:
  - Better control of boundary conditions
  - Batch trimming easier (handle base substrates instead of individual sensors)

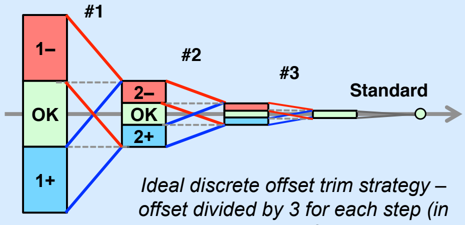


Batch trimming jig based on a standard probe card, with lever to apply calibration force

Production steps

1. Sensor substrate: thick-film process
2. Sensor substrate: mounting of electronics components
3. Sensor substrate: adhesive bonding of force-centring pin (dispense of silicone glue)
4. Singulation of sensor plates from sensor substrate
5. Base substrate: adhesive bonding of completed sensor plate
6. Base substrate: batch trimming
7. Singulation of completed sensors

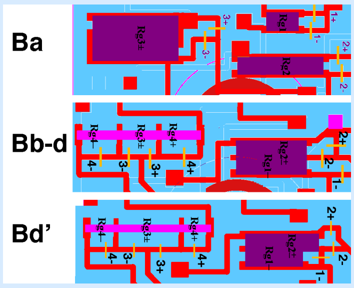
Discrete + standard offset trimming



Ideal discrete offset trim strategy – offset divided by 3 for each step (in practice not so favourable)

In principle:

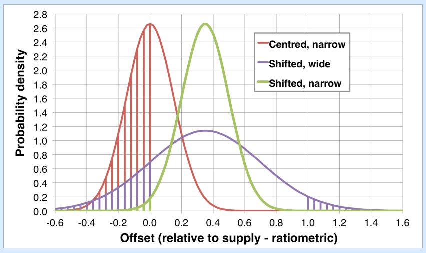
- Discrete trim = conductor cut - no microcracks in resistor
- Standard resistor trim only for last step
- Trim cuts (discrete + standard) essentially additive
- Three possibilities:
  1. No activation (OK)
  2. Positive offset shift
  3. Negative offset shift
- Ideally, offset range divided by 3 each step – in practice influenced by dispersion, layout issues, etc.



Layout changes in different versions to account for various issues

In practice – actual layout changes:

- Poor matching between compositions 10 kΩ (bridge + coarse discrete trims) & 100 Ω (finest discrete + analogue trims) – must introduce extra overlap (3± and 4± in versions after Ba)
- Layout: sometimes more favourable to duplicate resistor (e.g. 4±)
- No 1+ trim for single-pass adjustment using amplified sensor output (see below)

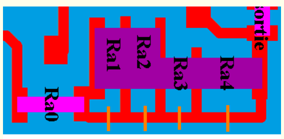


Schematic offset distributions (hatched areas not measurable due to amplifier saturation)

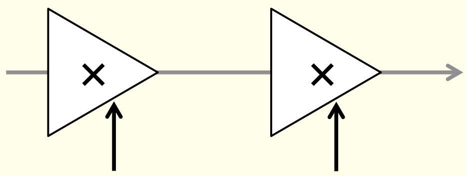
Direct adjustment of amplified output

- Cannot measure offsets <0 (amplifier in negative saturation):
  - Offset centred on 0 not favourable – shift introduced by making one bridge resistor slightly larger
  - "1+" cut not useful
- Narrow offset distribution required to avoid saturation – initial gain must be small, then raised in final adjustment

Discrete + standard gain trim



Layout of discrete gain-setting resistors (Ra0 small in 100 Ω paste, Ra1…4 in 10 kΩ paste)



Configuration:
a0 + a1×n, n = 0…15

Final gain (span) trim:
~0.8 …

Multiplicative circuit

- Settable discrete factor for gain configuration after offset adjustment
  - Very small initial Ra0 value to avoid saturation during offset trim (Ra0 ~ 0,1×Ra1)
  - Binary progression Ra1:2:3:4 ~ 1:2:4:8 for configuration of gain according to sensor variant, etc.
- Final gain adjustment using standard resistor cuts
  - Multiplicative with discrete factor = valid for all gain ranges
  - Designed for moderate gain increase (×1…2)
  - Can actually accommodate slight decreases (~×0.8) and larger increases (up to ca. ×5)