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

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Sensor & sensing principle

Discrete + standard offset trimming

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.

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 B)
- Layout: sometimes more favourable to duplicate resistor (e.g. 4±)
- No 1+ trim for single-pass adjustment using amplified sensor output (see below)

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

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)

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)

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

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