12 – Sealed passive devices

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Sealing passive components in vacuum or in controlled atmospheres to prevent parametric drifts due to dust or moisture or for other technical reasons was common practice. Most of the sealing techniques were acquired from vacuum tubes industry which in many cases became direct supplier for sealed passive components.

Fig. 12.1 - A sealed coil, the 1212893 made by General Electric, was used in the local oscillator of some Crosley car radios. Vacuum sealed tuning components, inductors and capacitors, were commonly used in aircraft and in military equipment to protect them from dust, moisture and condensation.

12.1 - Relays

In this section we find a survey of special relays generally characterized for having contacts sealed into a sealed envelope.

- **Vacuum relays**: used for RF or high voltage switching. Vacuum offers high dielectric strength, eight times greater than air, making it possible the construction of small and lightweight relays capable of uniform operation regardless of the external environment. Since no oxidation takes place in vacuum, contacts can also be made of low-resistance materials as copper or silver. In some high current pulsed operations, such as in capacitor discharge, a controlled atmosphere of sulphur hexafluoride, SF6, is added to facilitate conduction by ionization during contact bouncing. In early models, up to the sixties, glass was used for envelopes. Ceramic types are still in use today.

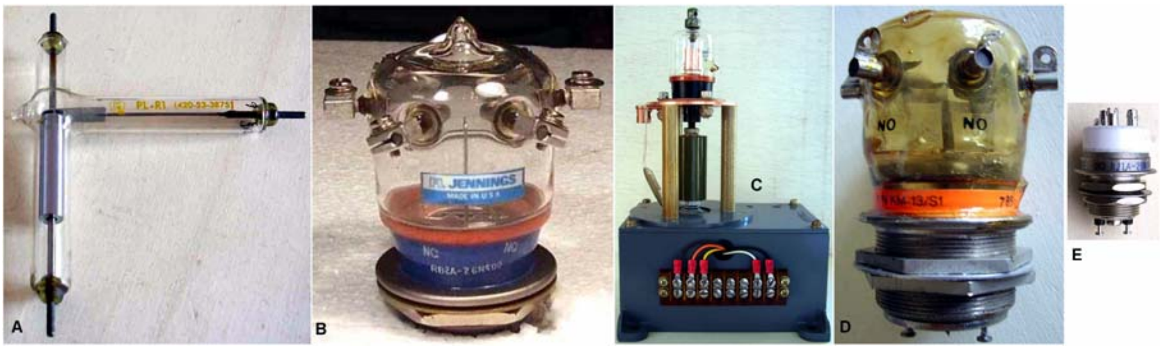

Fig. 12.2 - Vacuum relays. A) PL-R1 and the many equivalents, as 5TA-75 and Eimac VS-2 were rated for 20 kV at 7.5 A up to 15 MHz and 5 A up to 30 MHz. B) RB2A DPDT relay is rated for 20 A at 20 kV. The coil is in the screw mount base. C) R5C4304 is a high-power contactor capable of switching up to 50 A at 40 kV. D) KM13-S1 is a gas filled DPDT relay, used for handling the discharge of capacitors, E) RJ1A is a modern ceramic relay rated for 3.5 kV at 18 A.

- **Mercury relays.** In these types mercury is used to make bounce-free contact, also offering always renewed contact surface with few milliohms typical resistance. Mercury wetted reed relays were commonly used for switching low level signals with operating and release time in the order of very few milliseconds. Large mercury displacement contactors are used to smoothly switch tens of amperes at some hundreds volts. Operating time is in the order of tens of milliseconds after the coil is energized. The magnetic field pulls down an iron plunger, otherwise floating on the mercury surface. The upward displacement of the mercury closes the circuit between the contacts, usually made of tungsten. The bounce free operation of mercury relays makes them ideally suited for generating pulses with sub-nanosecond rise and fall time.

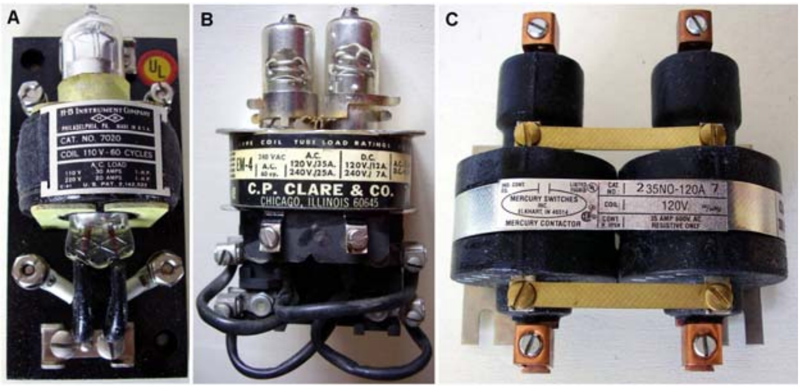

Fig. 12.3 - Samples of mercury displacement contactors. Even if hardly available, due to the indiscriminate banning of the mercury, still today these are the most reliable power contactors one could wish. Their operation is quiet, fast and safe, no bounce and always fresh contact surface. Even their release is absolutely safe, depending only by the force of gravity once the coil is deenergized. A) H-B 7020 was rated for 30 A at 110 V or 20 A at 220 V. B) Clare EM-4 was a double pole contactor, 25 A at 240 V. C) A modern unit with stainless steel enclosures, the 235NO-120A. 35 A at 600 V max ratings, resistive load. This type is specified for 250.000 cycles, with 3 milliohms maximum contact resistance through the life.

- **Sensitive relays**, in which vacuum prevents oxidation of the contact surfaces. Also included samples of hot-wire relays, sensitive to feeble current variations and used to protect circuits against overload conditions. Here operation is based upon the thermal elongation of a tiny wire and vacuum is used to prevent convection cooling of the wire.
- **Thermal delay relays**, mainly used to delay the application of the plate voltage after the cathode warm-up in power tubes. Generally based upon a heater wound close to a bi-metal strip. Heat slowly warps the bi-metal until the contact on the strip touches a fixed contact.
- **Vacuum switches**, also including reed switch ampoules

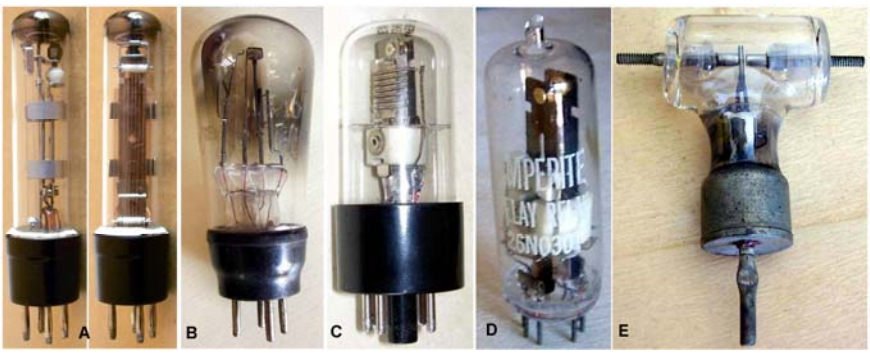

Fig. 12.4 – A) Two views of a high-sensitivity hot wire relay, the Sunvic 602. In these relays the heat generated by the current flowing in the long wire causes its elongation and the actuation of the bistable switch. Trip current is in the order of few tens of milliamps. B) DLS10 was one of the older British thermal delay relay. C) Amperite 115NO5 was an octal based thermal delay relay. D) 26NO30T is one of the miniature 9-pin base thermal delay relay. E) 1S21 was a vacuum switch designed by General Electric.

12.2 Opto couplers

In this family of components the light source is a lamp, incandescent or neon, coupled with a photoresistor. Used in many applications, among which the most fine I remember are a volume compression and expansion circuit and some choppers for amplifying feeble DC signals.

12.3 – Vacuum sealed resonating devices: quartz crystals, tuning forks, mechanical filters

Here we find several component families in which vacuum operation improves overall performances, by reducing damping due to the air and then increasing Q of resonators.

Piezoelectric properties of some crystals were already known since the nineteenth century. It was only in 1926 that the WEAF Station in New York started the transmission using the first crystal-controlled broadcasting station built by ATT Company. Frequency-to-temperature coefficient of quartz resonators could be negative, zero or positive depending upon the crystal cut with respect to the axis, the mode of vibration and the temperature itself. The first approach to stabilize the frequency over the entire operating temperature range was the use of thermostatic ovens. Anyway evacuated envelopes increase Q, by eliminating oscillation damping due to air, and reduce ageing due to dust or oxidation. The collection includes several hermetically sealed quartz resonators and even some thermostatic ovens used in precision instrumentation.

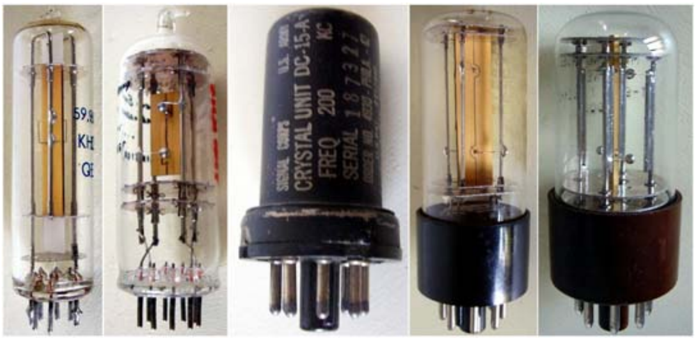

Fig. 12.5 – Samples of precision quartz crystals, all vacuum sealed to prevent the oscillation damping due to the atmosphere.

Other frequency-controlling devices were made enclosed in vacuum sealed envelopes, to prevent adverse influence by environmental conditions. The collection includes a variety of such devices, tuning coils, tuning forks and magnetostrictive mechanical filters. Fused quartz was also used to build multiple reflection delay lines, used as recirculating mass storage memory in old computer mainframes in the fifties.

Another very special sealed device is the vibrating capacitor. It was proposed as a sort of parametric amplifier for measuring currents as low as the one given by the flow of 500 electrons per second.

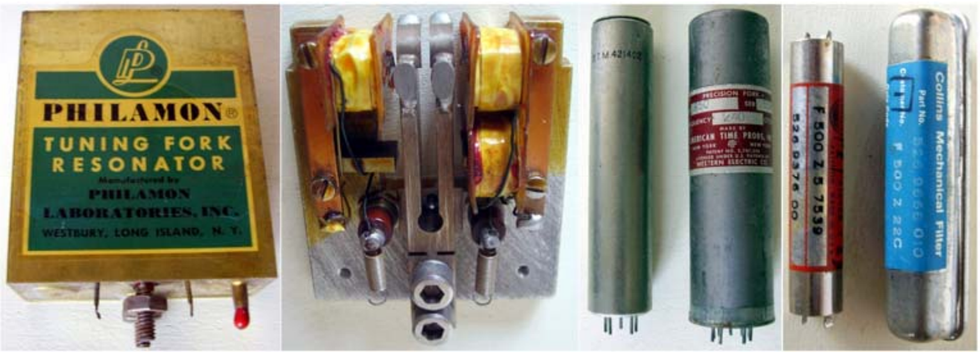

Fig. 12.6 – Samples of tuning forks, used to precisely control oscillations at very low frequency, typically up to about 1 KHz. The latest photo shows a couple of Collins mechanical filters, used as very high Q filters in the IF sections of AM receivers.

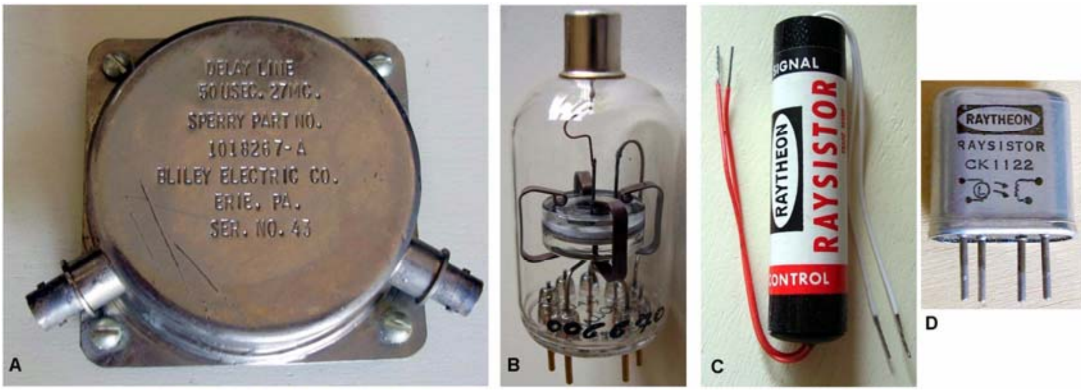

Fig. 12.7 – A) Fused quartz was also the basic material that made possible building stable [delay lines], used as mass storage in early computers. The above sample had a capacity of 1.350 bits. B) Philips [XL 7900/03] was a very special device designed to measure currents of order of magnitude around attoamperes. With an input resistance higher than 1000 teraohms, this vibrating capacitor was used as chopper in an amplifier capable of measuring the extremely small current generated by the flow of 500 electrons per second. C) Raytheon [CK-2129] was an optocoupler with a neon lamp as light source. D) In the [CK-1122] an incandescent lamp, 10 V at 17 mA, was used as light source.

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