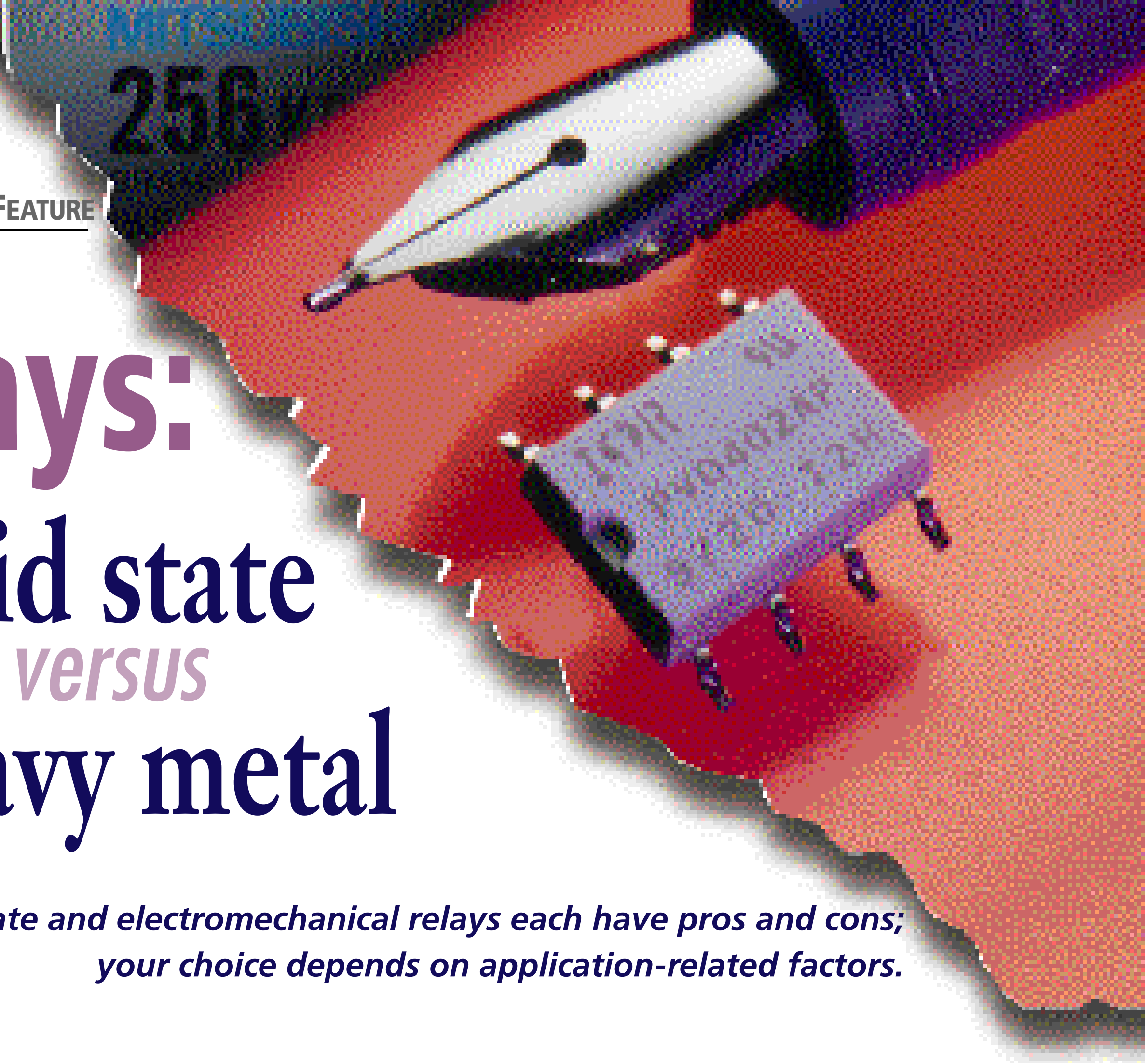



# Relays: solid state versus heavy metal

*Solid-state and electromechanical relays each have pros and cons; your choice depends on application-related factors.*

Relays have been switching signals since the days of the venerable telegraph key. They're available in myriad form factors and ratings, with a vast array of contact configurations. In many applications, you have the choice between solid-state relays (SSRs) and electromechanical relays (EMRs). Advances in semiconductor technology have spawned SSRs that offer clear advantages over EMRs. However, don't discount EMRs—the technology and performance of these devices are also steadily evolving; as a result, EMRs are often the switching elements of choice. An overview of the relative merits and demerits of the two types, along with a sampling of recent products, may provide some insights into the selection process.

A glance at the technology involved in SSRs and EMRs might prove useful. An SSR contains one or more LEDs in the input (drive) section (**Figure 1a**). Adding the LED connected by the dashed lines provides bipolar operation. The SSR provides optical coupling to a photodiode array, which in turn connects to driver circuitry that provides an interface to the switching device or devices at the output.

**Figures 1b** through **1f** show some, but not all, of the output structures in SSRs. The dual-MOSFET output in **Figure 1b** provides bidirectional switching and handles ac loads, as does the triac in **Figure 1e**. The bipolar transistor, insulated-gate bipolar transistor (IGBT), and SCR in **Figures 1c**, **1d**, and **1f**, respectively, are unidirectional switches that accommodate dc loads.

Many SSRs that accommodate ac loads incorporate "zero-cross" circuitry. This feature ensures that the switching device turns on at the zero-crossing point of

**SSRs *versus* EMRs**

the ac voltage applied to the load. Several SSRs that incorporate triacs provide a built-in series-RC snubber network to protect the triac against line-voltage surges. A snubber protects the triac against small to moderate surges; for more serious overvoltages, you should connect a surge suppressor to prevent triac burnout.

The output structures in **Figure 1** represent only a small portion of what's available. The LH Series of single and dual SSRs from Siemens, for example, offers 21 versions with MOSFET, bipolar, Darlington, and photodiode outputs, as well as with switched diode bridges. I/O isolation for the LH devices is 3750 or 5300V rms, depending on the version. These high isolation voltages make the SSRs well-suited for telecomm applications. As with all SSRs, the LH relays are easy to drive from logic circuitry. The input LEDs require only 2 to 3 mA of forward current to fully turn on the SSRs.

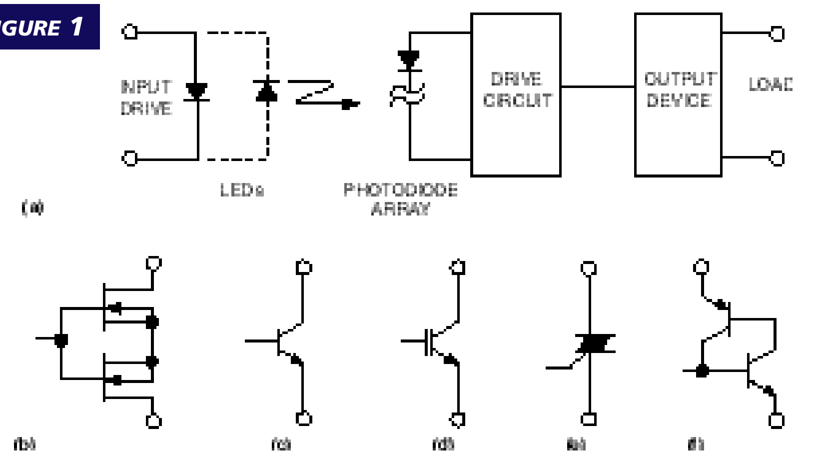
A range of output configurations is also available in CP Clare's narrow-SOIC family of SSRs. The series offers unipolar and bipolar inputs; MOSFET, bipolar, and Darlington outputs; and other amenities, such as zener protection diodes and full-wave diode bridges. The SSRs (from both CP Clare and Siemens) with MOSFET and bipolar outputs and diode bridges are eminently suitable for telecomm applications, such as DAAs (data-access arrangements).

The CP Clare narrow-SOIC SSR family is also available in small flat packs, which are useful in PCMCIA applications, for example. International Rectifier's PVT422P Series is also available in PCMCIA-compliant, thin (2-mm-maximum) packages. The PVT422P is a dual, MOSFET-output SSR that meets all telephony standards. Touted as the smallest SSRs available, Aromat's AQY210/214/414 relays come in miniature four-pin SO packages. They handle loads to 400V, 100 mA and cost $2 (1000).

**@a glance**

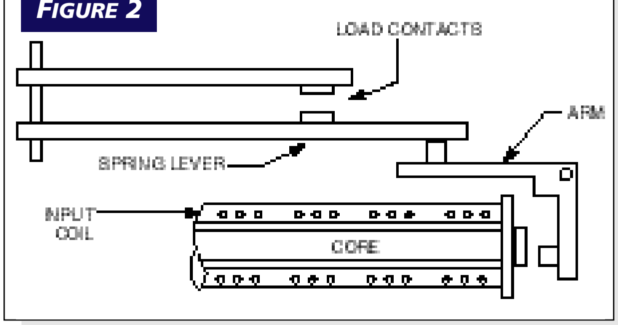
- Solid-state relays (SSRs) need protective measures in spiky environments.
- A multipole electromechanical relay (EMR) can often beat multiple SSRs in volumetric efficiency.
- Carefully check EMR specs for life expectancy at full load.
- Use an EMR for the lowest off-state leakage current; use an SSR for high I/O isolation.

**FIGURE 1**




**SSRs use photocoupling (a) to achieve high I/O isolation; they're available with a variety of output structures (b through f).**

**FIGURE 2**




**Classic EMRs use a solenoid-type action to pull in a lever that pushes the output contacts together; a spring pulls the contacts apart.**

**Figure 2**, derived from **Reference 1**, shows the topology of a typical EMR. The input (drive) voltage magnetizes the core, which then pulls the arm toward itself. This action makes the output contacts touch, thereby closing the load circuit. Upon removal of the input voltage, the spring lever pushes the contacts away from each other, thus breaking the load circuit. Another type of EMR, the reed relay, uses magnetic-material reeds encased in a glass tube. A coil external to the tube exerts a magnetic field that causes the reeds to contact each other.

## SSR versus EMR

**Table 1**, adapted from **Reference 2**, gives some of the relative advantages and disadvantages of SSRs and EMRs. An "advantage," of course, depends on the application. For example, acoustical noise, an ostensible disadvantage of EMRs, is of no consequence in a sealed box mounted 35 ft high on a telephone pole. And, limited operating life poses no problems in a system that might demand only a couple of hundred switching cycles in its lifetime.

Some of the pros and cons in **Table 1** can be important in particular applications. Some EMRs are clearly contraindicated, for example, in a system that uses millions of switching cycles. An SSR has no wear-out mechanism and, barring silicon defects, can accom-

**SSRs versus EMRs**

modate an infinite number of switching cycles. A typical life-expectancy spec for a power EMR might read, "minimum operations: $3\times10^4$ cycles at 12A, 125V ac." This kind of spec is fine for household appliances or office machines you might turn on and off once a day, but it falls short for equipment that uses large numbers of switching cycles. Note, however, that some low-power EMRs, notably reed relays, can offer very high life expectancy: for example, 250 million to 1 billion cycles.

One of the cons of SSRs, low to moderate volumetric efficiencies, might seem paradoxical, because solid-state devices are always smaller than their electromechanical counterparts, right? Not always. SSRs are restricted to single-pole, NO configurations, and, as a consequence, you might need several packages to implement a multipole design. EMRs, on the other hand, can offer you just about all the poles you need in one package. In most cases, however, an SSR is significantly smaller and lighter than its EMR counterpart. This factor, along with the SSR's superior resistance to shock and vibration, makes the SSR the candidate of choice in harsh motional-environment systems.

EMRs outperform SSRs in some important electrical specs. A typical EMR might spec on-resistance of 100 mΩ versus the SSR's 10Ω. The results are increased current capacity and less signal attenuation for the EMR. Output capacitance is another area of superiority for EMRs—typically 1 pF versus the SSR's 20 pF or greater. This factor is important in RF applications. Several specialized reed relays, for example, are optimized for RF switching, with tightly controlled 50Ω impedance matching.

**EMRs suit RF applications**

**Reference 3** provides an in-depth analysis of the RF performance of reed relays in 50Ω systems. The paper explores such critical parameters as frequency response, characteristic impedance, pulse rise time, voltage standing-wave ratio (VSWR), insertion loss, isolation, and transmission and reflection data. Two recent families of RF-specialized reed relays are available in a miniature, surface-mount format.

**TABLE 1—SSR AND EMR PROS AND CONS**

| SSR | EMR |
|---|---|
| **Pros** | |
| Long (theoretically infinite) operating life | Available in myriad multipole formats and contact ratings |
| High reliability | Low off-state leakage |
| Compatibility with logic ICs | High resistance to EMI and overvoltages |
| High switching speed | High isolation between outputs |
| No contact bounce | Low cost per contact |
| No arcing or sparking | Large number of sources |
| No EMI from contact commutation | Available in extremely high voltage and current ratings |
| No acoustical noise | Very low on-resistance |
| High resistance to shock and vibration | Low output capacitance |
| High input-output isolation | |
| **Cons** | |
| Low to moderate volumetric efficiencies because of single-pole configurations | Shorter operating life |
| Heat sink often required | Longer actuation time |
| Higher price per contact | Contact bounce and arcing |
| Higher off-state leakage | Higher drive requirements |
| Lower output-output isolation | Lower shock and vibration resistance |
| Higher output capacitance | Greater weight |
| Higher on-resistance | Acoustical noise |
| | Switching-induced EMI |

The 9800 Series from Coto Technology comes in axial, gull-wing, and J-lead formats. Its data sheet includes curves for 100-psec-step pulse response, delay time, transmission characteristics (frequency response), and return loss. Its maximum contact resistance is 200 mΩ, and its life expectancy for a 50-mA load is $100\times10^6$ operations (defined as an increase of contact resistance to 500 mΩ). The 9800 devices include a suppression network across the coil, comprising a 20V zener diode in series with a 1N4002 diode.

The surface-mount MRF Series from CP Clare also comes in axial, gull-wing, and J-lead formats. The RF curves (to 3 GHz) in the series data sheet cover VSWR, insertion loss, rise time, and isolation. The series' life expectancy for a 10-mA load is $200\times10^6$ operations. The operation and release times for both the Coto and CP Clare relays are 200 and 50 µsec, respectively. The MRF series is available in non-RF (MRF4) and RF (MRF8) versions. The RF version incorporates a coaxial shield. American Relays Inc also offers gull-wing and J-lead coaxial-shield reed relays for RF applications.

Reeds are not the only EMR types suitable for RF systems. A family of TO-5 bypass relays from Teledyne Relays provides RF performance characterized to 3 GHz. A "bypass" relay is designed to shunt a faulty RF amplifier—one mounted on an antenna masthead, for example. The Teledyne family is available in NC (RF310, RF313) and NO (RF320, RF323) formats. **Figures 3b** and **3c** show the NC and NO configurations, respectively, compared with a classic dpdt connection for amplifier-bypass systems. The data-sheet curves for the Teledyne family cover VSWR and insertion loss to 3 GHz. Life expectancy is $10^7$ cycles for low-level RF signals. **Reference 4** gives detailed application information for the bypass-relay family.

**Relays for telecomm**

As mentioned, SSRs offer several desirable attributes for telecomm applications—theoretically infinite lifetimes and high I/O isolation, for example. The G2 Series of telecomm relays from

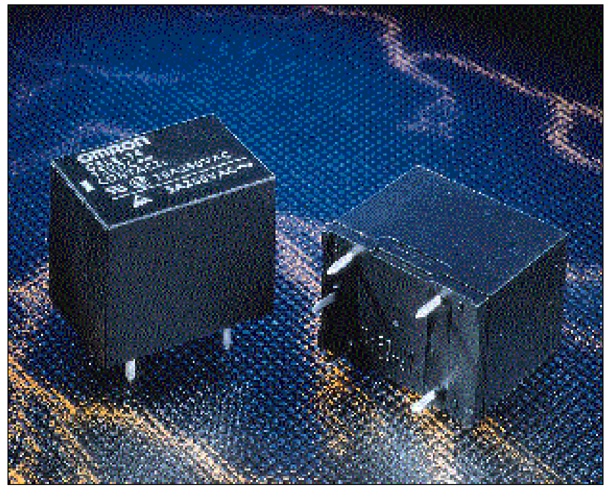
## SSRs *versus* EMRs

Coto Technology typifies what's available for telecomm use. The G2-1T01, for example, offers a MOSFET-output relay and a bipolar-output switch for on/off-hook control and for ring and loop-current detection (**Figure 4**).

For on/off-hook control, the MOSFET section functions as a switch hook to make a connection to the telephone loop. In the off-state (on-hook) condition, the MOSFET pair provides 1000-MΩ minimum resistance. I/O isolation resistance is 450 MΩ minimum, tested at 3750V rms. In the bipolar portion of the SSR, the antiparallel input LEDs conduct on both halves of the ac ring signal. Upon ring detection, the output phototransistor delivers a full-wave-rectified ring signal. With the antiparallel LEDs connected in series with the phone line, the bipolar portion also provides loop-current detection.

A dual-pole, MOSFET-output telecomm SSR from International Rectifier is the first in the industry that does not de-rate load current when both channels are conducting, according to the company. The PVT322 Series handles ±250V maximum load voltage and conducts 170-mA load current per channel with 10Ω-maximum on-resistance. The SSRs require only 2 mA of LED current for actuation, making them easy to drive from TTL or CMOS logic. I/O isolation is 4000V rms, which allows the SSRs to meet all safety standards and regulations.

A complete DAA implementation using SSRs is available from CP Clare. The CYG2911 module provides a full telephone-line interface plus caller ID and another-phone-off-hook sensing. This sensing feature is important for cable-TV set-top boxes and direct-broadcast satellite units that require immediate disconnection of the DAA from the phone line when a user needs to place an emergency 911 call. Another version, the CYG2300, provides a complete interface for products used with the German Post, Telephone, and Telegraph (PTT). The CYG2911 and CYG2300 cost $12.90 and $15.75 (5000), respectively.




**EMRs from Omron eschew environment-hostile cadmium and target HVAC, automotive, and appliance applications.**

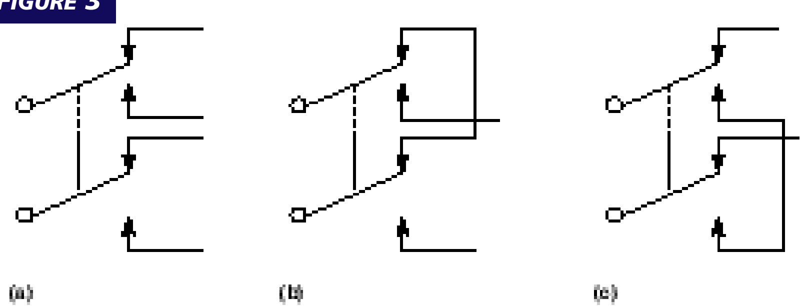
Statements about the suitability of SSRs for telecomm applications notwithstanding, EMRs are still alive and well in these systems, and new and improved models emerge constantly. Aromat's HX Series of nonpolarized EMRs, for example, provides switching to 1A in a miniature 7.4×15×9.4-mm form factor. Contact resistance is 100 mΩ maximum (an order of magnitude lower than many SSR figures), insulation resistance is $10^9$Ω at 500V dc, and life expectancy is $10^7$ operations.

Miniature EMRs from American Zettler also target telecomm applications. The single-pole AZ955 and double-pole 822 use a dual-inline footprint and meet the FCC Part 68 spec for 1000V dielectric strength and 1500V lightning surge. Both devices operate with a low 150 mW of coil power. Their mechanical life expectancy is $10^7$ operations; electrical life expectancy is a function of the load voltage, current, and inductive or noninductive nature. The company furnishes a life-expectancy table that relates these factors. The AZ955 and 822 cost $1.25 and $1.49 (1000), respectively.

A reed relay from Hamlin targeting telecomm applications comes in a miniature single-inline package. The Form B (NC) relay has a contact rating of 10W, 200V dc, 0.5A and costs $0.85 (10,000). Hasco offers a low-profile dpdt relay that's available in latching and nonlatching versions. The T Series switches 125V ac or dc at 1A. Its life expectancy is $10^8$ cycles. The T Series costs $0.72 (25,000).

This discussion of telecomm applications brings to mind one of the pro factors for EMRs in **Table 1**: high resistance to electromagnetic interference and overvoltages. It's indisputable that EMRs are more immune to damage from overvoltage conditions. A telecomm SSR might spec, for example, a contact-to-contact voltage range of ±250V. Excursions beyond that range can damage the SSR. The contacts in telecomm EMRs can withstand

**FIGURE 3**




**Bypass relays (b) and (c) from Teledyne Relays reduce the number of interconnections from four to two, compared with a classic dpdt bypass configuration (a).**

**SSRs *versus* EMRs**

much higher voltages.

It's evident, therefore, that you must adopt protective measures for SSRs used in telecomm systems, which can often abound in spikes and inductive kicks on the lines. **Reference 5** gives comprehensive advice on protecting telecomm SSRs. The paper discusses the use of zener diodes, metal-oxide varistors, and transient-voltage suppressors in a variety of DAA configurations.

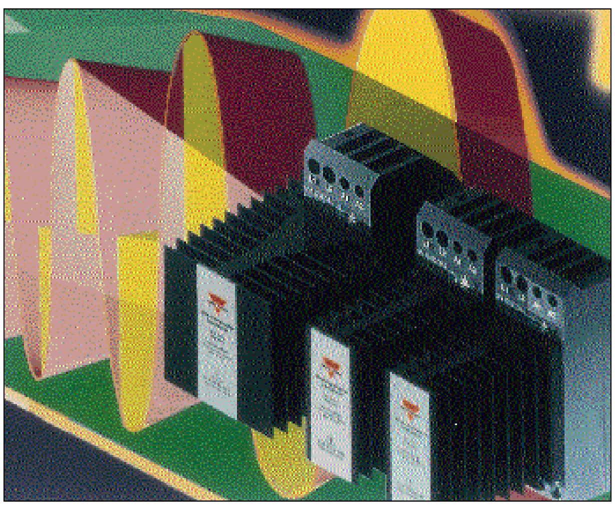
### High-power relays

As **Table 1** shows, EMRs usually have an edge over SSRs in applications requiring extremely high voltages and currents. The SSRs' limitations come from the voltage-breakdown and on-resistance characteristics inherent in silicon structures. Some examples of EMRs' voltage and current capabilities come from CII Technologies' Kilovac division. Two recent reed relays handle 3 kV, 2A and 5 kV, 5A. Both relays are available in NO models with a choice of 5, 12, or 24V-dc coils. The 3-kV S02DNA costs $29 (1000); the 15-kV S05MT costs $39 (1000).

A battery-disconnect relay from CII-Kilovac, designed for electric vehicles, handles 400A of continuous load current. The EV 250-1A operates at 320V and specs 0.3-mΩ maximum on-resistance. The relay's role is to disconnect the battery in the event of an electrical malfunction. The EMR uses special vacuum-sealing and arc-control techniques to survive the large voltage and current interruptions. The EV 250-1A costs $100 (10,000).

The CP Series of automotive relays from Aromat packs high current-carrying capacity in a 14×13×9.5-mm package. The EMRs handle 20A at 14V dc and spec 100-mΩ on-resistance. The life expectancy is $10^7$ mechanical operations at 120 operations per minute. The maximum operating speed with the rated load is six operations per minute. Omron's 19-mm-high G5LE Series targets HVAC, appliance, security, and automotive applications. It handles 10A at 120V ac and operates to 85°C.

Like many recent EMRs, the G5LE dispenses with environmentally damaging cadmium in its contact system in favor of a silver/tin-oxide system. The relay costs $0.94 (1000). Stetron's ST 90H EMR comes in spst-NO, spst-NC, and spdt formats. The relay handles 30A at 14V dc or 240V ac and specs $10^7$ operations (mechanical) or $10^5$ operations (full resistive load).

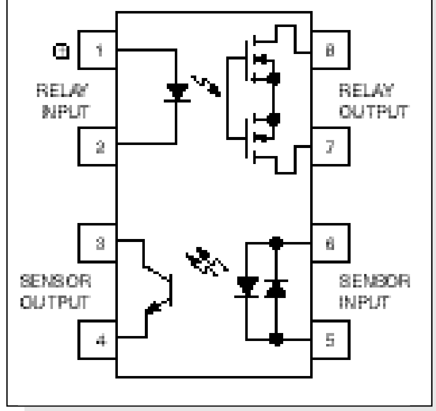


**Solitron Series SSRs from Carlo Gavazzi mount on DIN rails and incorporate front-mounted heat sinks.**

Though SSRs can't match the current-carrying capacity and low on-resistance of the biggest EMRs, they're by no means wimpy. The CMD Series of SSRs from Crydom comprises 18 models that handle 25, 50, 75, 90, 110, and 125A at voltage ratings of 240, 480, and 600V ac. Note that the devices require user-supplied heat sinks to achieve the cited ratings. All models use back-to-back SCRs as the switching devices and spec 1.7V maximum on-state voltage. CMD relays cost $26.20 to $34.04 (100).

Crydom and Carlo Gavazzi supply DIN rail-mounted SSRs that incorporate an integrated heat sink. The Crydom CoolPak Series is available in 12 models that handle 35 to 65A at 240 to 600V ac. Carlo Gavazzi's Solitron Series offers single- or double-pole models that switch either 25 or 50A at 230 or 480V ac. The Crydom SSRs cost $34.05 to $60.32 (100).

**FIGURE 4**




**A typical telecomm SSR uses source-to-source MOSFETs for on/off-hook control and uses a bipolar switch for ring and loop-current detection.**

### Specialized relays

Some applications require relays with special characteristics. SSR and EMR manufacturers have responded to these needs with various specialized devices. International Rectifier, for example, has responded to the worldwide outcry against mercury with its PVX6012 SSR. The relay, designed to replace mercury-wetted reed relays, uses an IGBT output structure. It handles 280W ac, 400W dc and uses 5 mA of actuation current. The output uses a pair of inverse-series-connected IGBTs. A diode across each IGBT provides low-drop conduction in the reverse polarity. Input-to-output isolation of 3750V rms meets all safety standards. The PVX6012 costs $3.60 (25,000).

Dissimilar metals in a conventional reed relay can introduce thermocouple-induced error voltages of tens to hundreds of microvolts. Coto Technology's 3500 and 3600 Series of reed relays combat the thermocouple problem by using a special thermal clip. The EMRs are available with maximum thermal-EMF ratings from 0.5 to 10 μV. The devices cost $4.18 (1000).

Another specialty in relay technolo-

SSRs *versus* EMRs

gy is the time-delay device. Amperite specializes in this type of relay. The DCR10 Series, for example, combines CMOS circuitry with EMR technology to provide time delays of 0.1 sec to 1000 hours. The relay has a knob-adjustable potentiometer. The DCR10 costs $42.48 (500). The SWUDC Series also uses CMOS circuitry with a potentiometer and a binary-coded DIP switch to provide time delays from 0.1 sec to 77.5 hours. The SWUDC costs $40.67 (500).

SSRs are making steady advances in performance, ratings, and versatility. EMRs are not ready to lie down and die, though; they're also improving in capabilities, compactness, and cost. Your choice of a relay type requires a careful consideration of the merits and demerits of the two types.

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4. Application Note, RF310/313/320/320 Relay Series, Teledyne Relays.
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