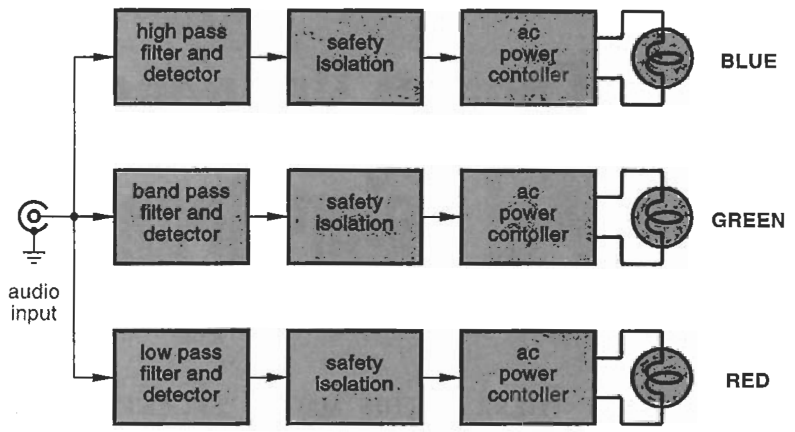

FIG. 2—HERE'S A BLOCK DIAGRAM of a classic color organ. The audio input gets filtered into three or more channels. Audio energy in each filter band sets the dynamic brightness of the chosen lamp color for that channel.

Color Organs and Psychedelic Lighting

I guess it's way past time to update certain ancient history. People have long wanted to relate music to colors in one way or another. Back in the 16th century, a Jesuit monk by the name of James Bertrand Castell created his *Clavier au Lumier*. That was sort of a harp with flat colored strings. The strings were viewed edge on. As the string was plucked, you could see all the vibrating colors.

The first "classic" electronic color organ designs appeared in the 1950s. One used *thyratron* "vacuum" tubes in a half-wave design that only lit the lamps to partial brightness. Another used high-mu pentode audio-output vacuum tubes to drive scads of series-connected and easily-burned-out #49 pilot-light strings.

Figure 2 shows the block diagram for a classic lamps-style color organ. The speaker-level input audio is somehow safety isolated and then lowpass, bandpass, or highpass filtered into (usually) three or more channels. Each channel's output is then converted into some DC control voltage. That DC control voltage then modulates a "power amplifier" of some sort. Which in turn relates the amount of audio energy in the band to the brightness of one or more colored lights. For instance, the lows might be red, the mid-ranges green, and the highs blue.

I designed and published my first three-channel solid state-color organ in April of 1963 in the now defunct magazine, *Electronics World*. That used brand-new (at the time) Silicon Controlled Rectifiers to control a few-hundred watts of lamps-per-channel. The SCRs were preceded by a full-wave rectifier. That design let the lamps go more or less smoothly from zero to full brightness. Input audio went through some LC ferrite-cup core filters, was converted to DC with germanium-diode rectifiers, and then was used to control the phase advance of the unijunction-transistor timing circuits. That design was followed a year later, in the January 1964 *Electronics World*, by a version that substituted neon lamp triggers for those costly unijunctions.

The next version appeared in the October 1965 issue of **Radio Electronics** (this magazine's predecessor). That was the first unit to use voltage-

AC PHASE CONTROL RESOURCES

P Claire 107 Audubon Road #8 Wakefield, MA 01880 (617) 246-4000	**International Rectifier** 233 Kansas St. El Segundo, CA 90245 (310) 322-3331	**NTE Electronics** 44 Farrand St. Bloomfield, NJ 07003 (201) 748-5089	**Signetics/Philips** PO Box 3409 Sunnyvale, CA 94088 (408) 991-2000
Crydom 411 N Central Avenue Glendale, CA 91203 (818) 956-3900	**LSI/CSI** 1235 Walt Whitman Rd. Melville, NY 11747 (516) 271-0400	**PCIM** 2472 Eastman Ave. #33-34 Ventura, CA 93003 (805) 658-0933	**Teccor Electronics** 1801 Hurd Dr. Irving, TX 75038 (214) 580-1515
Galco 26010 Pinehurst Dr. Madison Heights, MI 48071 (800) 521-1615	**Motorola** 5005 E McDowell Rd. Phoenix, AZ 85008 (800) 521-6274	**SGS-Thomson** 1000 E Bell Rd. Phoenix, AZ 85022 (602) 867-6259	**Texas Instruments** PO Box 809066 Dallas, TX 75380 (800) 336-5236
Grainger 2738 Fulton St. Chicago, IL 60612 (312) 638-0536	**Mouser Electronics** 11433 Woodside Avenue Santee, CA 92071 (800) 346-6873	**Siemens Components** 2191 Laurelwood Rd. Santa Clara, CA 95054 (408) 980-4500	**Thomson CFS** 40G Commerce Way Totowa, NJ 07511 (201) 812-9000

modulated, four-layer trigger diodes, and the first to provide a line filter to attack the bad AM radio interference common to color organs.

Skipping a few designs which are best left forgotten, next in line was my *Musette*, which appeared in the July 1965 issue of **Popular Electronics.** That was a five-channel unit that still featured SCRs and trigger-diode modulation. Filtering was done using resonant transformers. Color-coded background controls were added to improve the sensitivity and linearity. Brand new dichromic-filter spotlights were used to dramatically improve color purity.

What I first called *Stereo Lamps*, but some editor renamed *Hi Fi a Go Go* appeared in the July 1966 **Popular Electronics.** That was just a low-priced, compact and unfiltered single channel version. It was useful for psychedelic lighting applications.

I considered my "definitive" color organ to be the *Psychedelia I*, which appeared in the September 1969 issue of **Popular Electronics.** Innovations in that unit included the use of new low cost full-wave Triacs having built-in heat sinks, a brand new $1 integrated-circuit phase-controller circuit, and steep-skirted two-pole active filters having broad between-channel guard bands. The use of prismatic lenses on the display gave hex "flower power" types of patterns. You had a choice of three or six channels.

Phase Control Fundamentals

The fundamentals of an AC-power phase control appear in Fig. 3. A Triac is a fast, efficient, and high voltage power AC switch that is turned on by a brief and low-level pulse on its gate. The Triac then stays on for the remainder of the power-line half cycle. It automatically turns off when your main current drops to zero on the half-cycle zero. Triacs are fully bi-directional: either polarity of gate pulse can be applied on either polarity cycle.

If the Triac is pulsed very late in each half cycle, the duty cycle is very low; very little power reaches the load, say a lamp, and the lamp lights only dimly. When the Triac gets pulsed in mid cycle, around one half of the power reaches the lamp. When it gets pulsed very early, the lamp lights to nearly full brightness. Thus, you might want your input control voltage to determine the time delay after a zero crossing when the Triac turns on. The higher the voltage the *less* your delay.

A modern Triac circuit appears in Fig. 4. For most applications, safety isolation is *essential* to prevent deadly "hot chassis" shock hazards. That is the purpose of the Motorola MOC3010 optoTriac isolator. While you can get Triacs from *Radio Shack, Texas Instruments or Motorola*, the definitive source is Teccor.

Usually, you will want to run your optoisolator "backwards" (as shown in

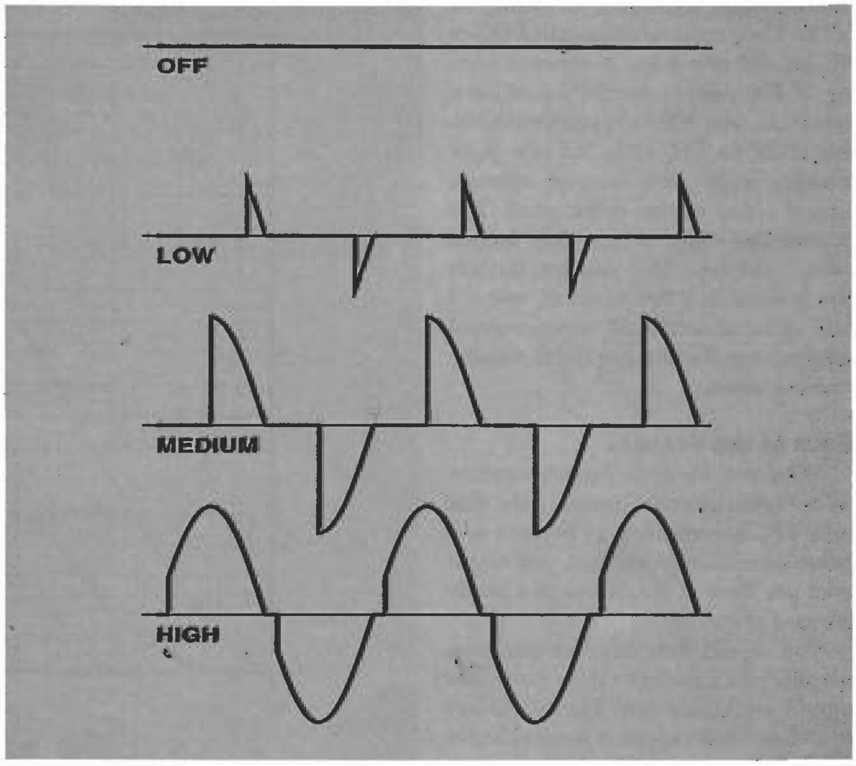

FIG. 3—THE FUNDAMENTALS BEHIND the phase control of AC power. The turn on of a Triac gets delayed after each AC half-power cycle. The longer the delay, the lower the load current. Simple phase control is useful for lamps, heaters, and AC/DC motors, But NOT for fluorescent lamps or induction motors.

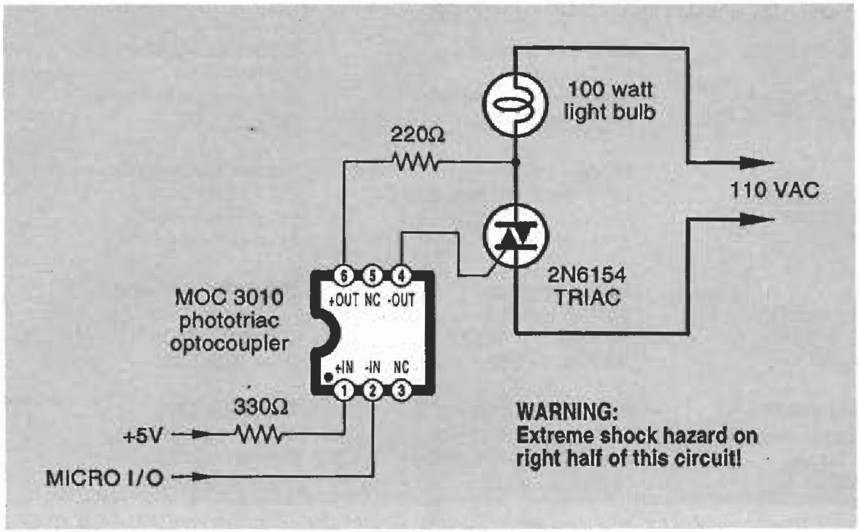

FIG. 4—A TYPICAL OUTPUT INTERFACE between a microcontroller and an AC power load. A one-piece solid state relay could be substituted. For a proportional phase control, a zero crossing reference must be provided.

The perceived brightness of a lamp is not at all linearly related to the phase angle. There are three reasons for that. First, the phase-angle versus power is an "S"-shaped curve rather than linear. Secondly, the eye is a nonlinear device that perceives light logarithmically. And thirdly, an incandescent lamp has a very nonlinear resistance at low brightness levels.

So, we take our new baby PIC and convert each input control voltage into an 8-bit number between 0 and 255. Then we use table lookup to find a new number that sets up an acceptable phase delay for the desired apparent brightness level. The table lookup should be closely matched to the lamps in use. Since your eye perceives equal brightness light in the ratio of one part green, two parts of red and three parts blue, you might want to select a different lookup for each color.

the figure) so that a low or logic zero input turns the Triac on, and vice versa. That's simply because many microcontrollers and other digital ICs are better at sinking current to ground.

Two sources of specialized phase control integrated circuits are LSI/CSI and Signetics Philips. You can also get one-piece modules which include both Triac and optoisolation from CP Claire, International Rectifier, Crydom, or NTE. They are sometimes called *DC-in AC-out solid state relays*. A minimum rating of 200 volts is needed for AC-line operation, with 400 volts recommended. But at $8 to $12 each, the one-piece modules might not be cost effective against a pair of one dollar parts. The heat-sinking options are also limited using modules. The smaller module power limit is a few hundred watts. I have gathered several AC power-control suppliers together for you as this month's resource sidebar.

Back to the Present

What can we do to further improve color organ designs? Obviously, the new baby PIC is screaming to be used as a phase controller. With care, you might even get three channels out of a single low cost chip!

You would first have to question whether you'd prefer to use a classic design or something new. The crucial key to a classic color organ is some effective display. Even with the best designs, viewing can get boring.

At any rate, if I were doing a new "classic" color organ, two features I would add are input compression and linearization. As Fig. 5 shows us, typical audio has ridiculously too much dynamic range for useful phase control of lights. Your lamps will be off or on most of the time, instead of smoothly tracking the music. Analog Devices has their low price SSM2165 speech-compression chip that should be ideal for this application.

The aim is to let music produce as many different brightness levels as possible. As before, you'd never let the lamps go completely off. A very low background level is a first step towards linearization. I guess I'd select digital bandpass filters these days. Both Maxim and Linear Technology have lots of fine selections for you.

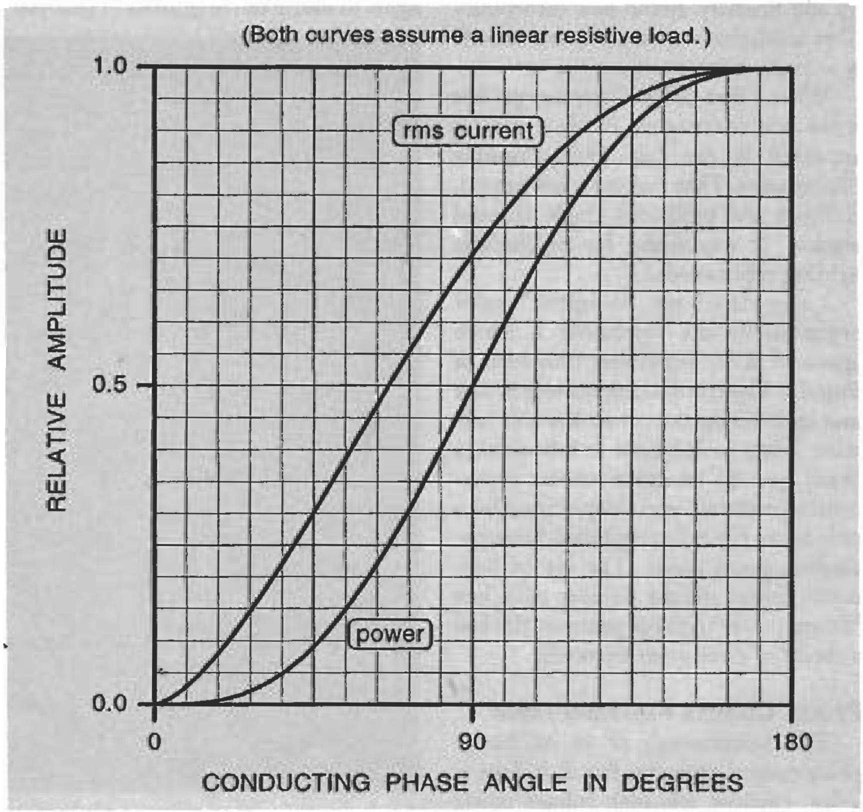

FIG. 5—THE "LINEAR" PORTION of an AC phase control has a sorely limited dynamic range of a mere ten to fifteen decibels. Linearity and dynamic range can both be greatly improved by using table lookup in a baby PIC.

NAMES AND NUMBERS

Ace Plastics 26 North Avenue Garwood, NJ 07027 (800) 695-4223	**Maxim** 120 San Gabriel Dr. Sunnyvale, CA 94086 (800) 998-8800
Analog Devices PO Box 9106 Norwood, MA 02062 (617) 329-4700	**Meredith Instruments** 5035 N 55th Ave. #5 Glendale, AZ 85301 (602) 934-9387
Brodhead Garrett PO Box 8102 Mansfield, OH 44901 (800) 321-6730	**Microchip Technology** 2355 W Chandler Blvd. Chandler AZ 85224 (602) 786-7200
Castcraft Box 17000 Memphis, TN 38187 (901) 682-0961	**MWK Industries** 1440 S State College Blvd. 3B Anaheim, CA 92806 (800) 356-7714
Contract Professional 125 Walnut Street Watertown, MA 02172 (617) 926-7077	**Parallax** 3805 Atherton Rd. #102 Rocklin, CA 95765 (916) 624-8333
Scott Edwards 964 Cactus Wren Lane Sierra Vista, AZ 85635 (520) 459-4802	**Rex Supply** 3715 Harrisburg Blvd. Houston, TX 77003 (800) 369-0669
KeelyNet BBS Box 1031 Mesquite, TX 75149 (214) 324-3501 BBS	**Stemgas Publishing** PO Box 328 Lancaster, PA 17608 (717) 392-0733
Lindsay Publications PO Box 538 Bradley, IL 60915 (815) 935-5353	**Synergetics** Box 809 Thatcher, AZ 85552 (520) 428-4073
Linear Technology 1630 McCarthy Blvd. Milpitas CA 95035 (408) 432-1900	**Tapestry** 431 Griggs Street N St Paul, MN 55104 (800) 876-3776

When you do your own design, do not forget to provide reliable safety isolation, always add some effective line noise filtering and shielding, and treat your input audio gently. Use the purest colors you can get. Avoid yellow because it typically overwhelms. Since an incandescent lamp is pretty much yellow to start with, filtering for other colors very much limits the light output. Go out of your way to prevent any and all white light from any pinholes, leaks, color recombination, or poor filters. There's a lot more on lamps and lighting resources in MUSE95.PDF. Available on www.tinaja.com or in the *Tech Musings* reprints. Grainger, of course, is your prime source for lighting options.

Going Non-Traditional

What about non-traditional color organ architectures? LEDs are one possibility, but power levels may be restricted, the blues will still be expensive, and you'd still be stuck with limited display options. Lasers are another possibility, but again the blues are a problem. (If you are still interested, you can find more on laser approaches from MWK Industries or Meredith Instruments.)

What if you instead combined a spectrum analyzer chip with a screen saver? The ultimate would be to use very sophisticated DSP techniques to attempt to isolate music instruments. Let each instrument be a color blob on the screen. Some kind of tracking comb filter, maybe. The louder the instrument, the bigger and brighter the chosen blob.

Those blobs could wander around lava lamp style, continually showing new and interesting variations. Different algorithms could also be keyed to mood or music style. Texas Instruments has a new DSP demo board with a full real-time audio spectrum analyzer built in. It might make an interesting front end for audio-to-color displays.

NEED HELP?

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