Tech Musings

February, 1996

Replacing a transformer
Variable gain amplifiers
Hobby robotics resources
New AGC amplifier chips
Digital potentiometer intro

One recent helpline caller wanted to replace a mystery power transformer on an older digital alarm clock. Firstoff, please note that transformers do *not* burn out by themselves. They always have help.

If you replace a transformer and don't fix the underlying problem, the new transformer will also burn up. The most likely causes are a shorted filter capacitor, a bad power diode or a blown regulator. Less likely could be lightning damage, input surges, or physical abuse.

Some four year old who thinks the clock was a piggy bank is yet another possibility. I once saw a floppy disk drive completely filled with 35 mm photo slides.

Back to the transformer. If at all possible, contact the manufacturer. Or else pick up the service info in *Electronic Servicing*, on-line, or by using one of those electronic repair classifieds. An accurate schematic makes things far easier.

Usually you are able to guess the secondary voltage by working back from the ratings of the filter cap or the regulator. A 7805 regulator needs four or more volts of headroom, so maybe something in the +10 vdc range for raw supply power. To get from the dc output voltage to the ac transformer voltage, add one for each diode drop and then multiply by 0.7. Or something like 8.4 volts in this example. Call it nine even.

The cubic volume of any 60 Hertz transformer pretty much determines its power rating. Maybe 5 watts for a one inch cube, 20 watts for a two, and 60 for a three.

Sometimes it is easiest to replace the entire supply with a wall mounted one. Another ploy is to pick any old larger 24 volt transformer and use a Variac or autotransformer to *slowly* bring the input voltage up to where things seem to be operating properly. A "somewhat higher" input should be just about right.

If all else fails, a final emergency procedure is to take the transformer apart and count the turns. The turns ratio is the same as the output voltage ratio. But note that the loaded output voltage might typically be 20 percent or so lower.

Electronic Gain Control

There are lots of times and places where you may want to electronically control the gain of some circuit stage. In AM radio, this is called *Automatic Volume Control*. AVC causes local and distant stations output at nearly the same volume. In a television set or communications gear, an AGC or *Automatic Gain Control* does nearly the same thing.

A gain control beastie known as a *Compressor* might bring microphone inputs up to some uniform level for recorders or mobile radio comm. A similar compressor misused in a tv studio can make commercials more obnoxious. In electronic music aps, a VCA (Voltage Controlled Amplifier) can set the attack-sustain-decay of an envelope waveshape.

The *manner* in which your gain varies with the controlling current or voltage can be quite important. The obvious *linear* choice usually has a restricted dynamic range. A *log* (or "by decibels") choice is often better for audio or communications.

Active filters and other frequency tracking applications work best with an *inverse* gain relationship. Because you are usually changing some time constant, and time rate is the inverse of frequency.

Regardless of what they are called, all electronic gain adjustment circuits are really a class of devices known as *two-quadrant multipliers*.

In which a unipolar dc level gets multiplied by an ac input signal to set the gain and produce an ac output.

One of the earliest gain controls was a vacuum tube called a *remote cutoff pentode*. The grid spacing was nonlinear, causing parts of the tube to stop amplifying before other portions did. As you increased the negative grid bias, the gain of the stage would progressively diminish.

The current gain of a transistor is a function of collector current. Certain early transistors were designed such that their beta -vs- collector current curve gave a linear gain. And thus gave an AGC action. These devices are long gone.

The most popular gain controlling schemes in use today involve…

Differential Amplifiers

The *differential amplifier* is by far the most significant analog circuit of all time. Diff amps can offer many amazing properties. One of which is that their open loop gain might be easily and remotely controlled.

I've shown one in its *single ended* form in figure one. Using matched transistors and zero input, the current from the current source should split evenly, half going to the left and half to the right. As the input voltage goes positive, the split changes, with more current going left. If the input swings negative, extra current goes to right. The output will be an amplified and *noninverted* replica of the input. We usually have voltage gain.

You might think of a single ended diff amp as an emitter follower that drives a *grounded base* stage. This

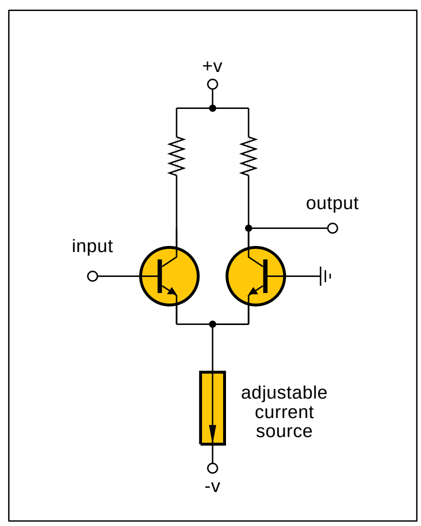

Fig. 1 – DIFFERENTIAL AMPLIFIER can be viewed as an emitter follower driving a grounded base stage. The current linearly sets the gain.

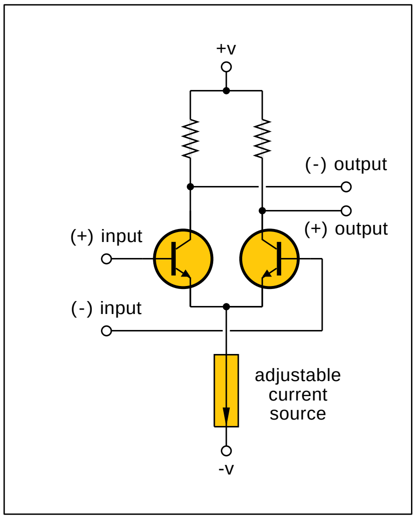

Fig. 2 – "FULL FEATURED" diff amp offers balanced inputs and outputs. Common mode signals are ignored.

particular emitter follower has a gain of 0.5, since its output impedance is driving an identical load.

The gain of a grounded base stage is the ratio of its input resistance to its output resistance. In this case, the input resistance is the impedance of a emitter-base diode.

A diode's impedance changes with the current through it. Using a crude formula of 26/i, where *i* is the current in mils. Thus, half a mil through a diode can provide you with a small signal impedance of 52 Ohms.

The key point: If you increase the current from your current source, the gain goes up. And vice versa. One use of a diff amp is as an electronic gain control.

Sometimes the current source itself gets adjusted by an external control voltage. Other times, a circuit called a *current mirror* can be used. Current mirrors let you "bounce" a control current off a negative supply rail or whatever. Giving you a choice of voltage or current control.

Let's say you have a 2.5K load. If half a mil from the current source goes to the right, that stage shown will have a gain of nearly 50. The left stage has a gain of 0.5 because it is driving a load equal to its output impedance. The total voltage gain will be something near 25.

A fully balanced diff amp appears in figure two. The *difference* between the input voltages gets amplified and becomes the *difference* between the output voltages. Besides doubling the gain, you pick up a tremendous new advantage: Any hum, noise or other signals that bounce the inputs up and down *together* are ignored!

This amazing property is called *common mode rejection*. Among its other benefits, CMR largely ignores power supply hum, bias shifts, and certain input ground loops.

You also have the choice of using inverting or noninverting outputs. Or using both inputs at once.

In lots of applications, negative feedback gets applied around one or more differential amplifiers. That is what op amps are all about. Such a feedback overrides the gain settings of individual internal stages.

Also note that the supply current is constant, regardless of input signal levels. The current from the current source just gets shifted right or left. But it always gets back together at the positive supply terminal.

A final unique feature of diff amps is that they limit cleanly and quickly on overdrive. The output voltage can go no higher than the supply and no lower than the load resistance times your maximum current source value. Transistor saturation can be easily prevented. Such *clipping* circuits are super important for FM mobile radio communications or tv audio.

One classic diff-amp gain control chip is the CA3080 transconductance amplifier. Around eighty cents last time I checked. Full details on this one appear in my *CMOS Cookbook*

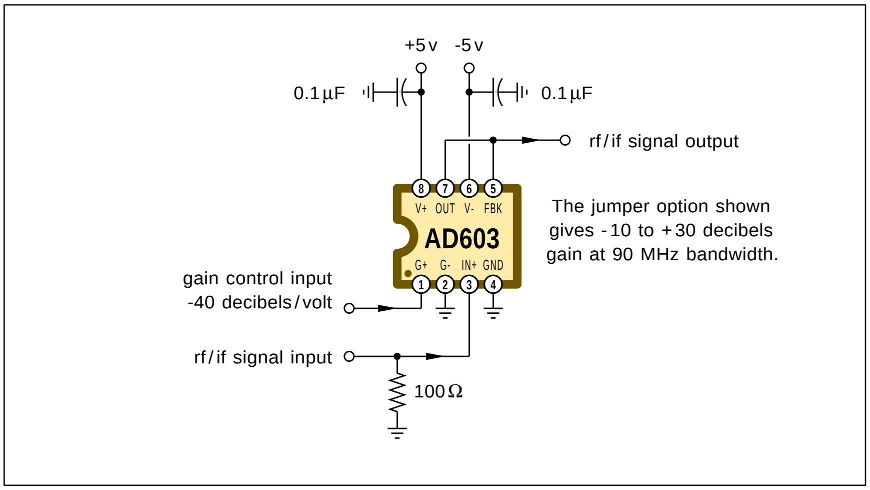

Fig. 3 – ANALOG DEVICES AD603 low noise variable gain amplifier. The control voltage works "by decibels" with a -40 db per volt sensitivity.

A New AGC Circuit

The folks at *Analog Devices* just came up with a new low noise AGC chip that seems really impressive. It is their AD603 variable gain amp. I have shown it in figure three. Its bandwidth is your choice of 9 or 90 MegaHertz. The gain is controlled *by decibels* with a 40 decibels per volt sensitivity. Stages may be cascaded for additional control range.

Their new chip uses a somewhat different approach to variable gain. An electrically adjustable attenuator gets placed in front of a fixed gain amplifier. The input noise is quite low. Noise figure problems can be further minimized by use of two stages with a "progressive build" or "delayed AGC" scheme. In which the second stage has its gain reduced *ahead* of the first stage.

Refer to their free data sheet for further schematics and applications.

Digital Potentiometers

There's also some fairly new kids on the electronic gain control block. These are *digital potentiometers* or EEPOTS. Who work just like an old fashioned resistance decade box. Typically, there'll be 64, 100, or 256 series resistors, and you will apply a command of one sort or another that picks a selected tap.

One advantage of digital pots is that they replace analog trimmers. These are easily set under automatic computer control. And do not drift out of spec with time.

Disadvantages include the limited

number of steps and certain slight nonlinearities caused by the internal MOS switches. Even using 256 steps, one end or the other could get real cramped if you really do need log or inverse gain relations.

You can cascade digital pots for more resolution. The 20% maximum gain nonlinearity of a direct cascade can be eliminated by buffering with an op amp. But with 4096 to 65,536 available levels, it's usually easier to precalculate your correct setting.

You usually have your choice of *rheostat* or *potentiometer* modes. The rheostat choice gives you a simple variable resistor. The potentiometer mode gives a resistance *ratio*. Just like a normal volume control.

Typical total resistance ranges are 10K, 50K, or 100K. Lower values are not too practical because of the on resistance of the MOS switches that are in the signal path.

Signals that you apply to the pots themselves can be analog, digital, or dc levels. But their levels always must remain somewhere between the supply voltage and ground.

Two examples are the dual AD8402 or the new quad AD8403 from *Analog Devices*. I've shown the basic setup in figure four. These chips can be controlled by a serial clock and data stream, following the formats shown in the data sheet.

Ten bits of data are needed. Two address which pot is chosen. Eight decide which switch position. Total time to change your switch position depends upon your input clock rate. Minimum is around 450 nsec.

Thus, you can make over half a million gain changes per second. If you really want to.

The *Basic Stamp* or another PIC microcontroller is ideal for this sort of control use.

A sneaky "cascade" trick lets you control any number of chips with a three wire interface. This is done by connecting the serial data out of the first stage to the serial data in of the second. The first ten data values get "used up" by the first stage. All the "extra" data values during a load get passed on. The second ten values will get grabbed by the second stage, and so on down the line.

These particular chips are volatile. They forget their previous values on power down. Thus, you will have to reinitialize them each time power to your circuit is reapplied.

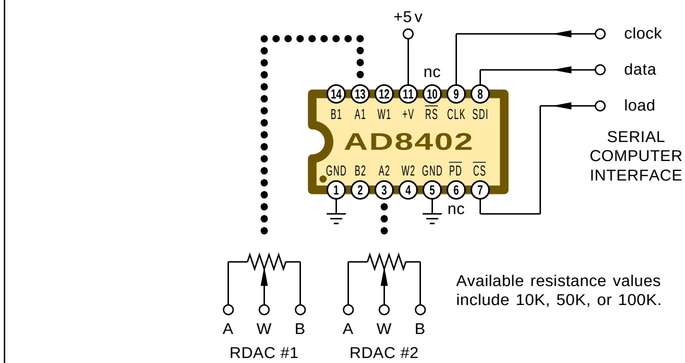

Fig. 4 – ANALOG DEVICES AD8402 dual digital potentiometer. Ten bits of serial data pick a "pot" and set it to one of 256 different "wiper" settings.

Current from the 3 or 5 volt supply can be as low as 5 microamps.

Be sure to carefully read the data sheet for more use details. Pin 6 can be used to disable the outputs, while pin 10 can be used to force both pots to their "mid wiper" position.

Another very interesting chip is the *National* LM1973 three-channel audio attenuator. Each channel has a digitally controllable log attenuator with a 76 decibel range. As with the AD4802, a three wire digital serial control is used.

Leading sources for other digital potentiometers include *Xicor*, *Dallas Semiconductor*, *Burr-Brown*, *Analog Devices*, and *National*. Bunches of variations are available that accept serial input data, that remember their old setting on power down, offer log steps, or an up-down count action. We might look at these in more detail in a future column.

More details on early *Xicor* chips appeared back in HACK01.PDF.

Speaking of switched resistors, I have just picked up some classic resistance substitution boxes. Some fine four decade *Shallco* switchable 0.1 to 100 decibel audio attenuators, too. Let me know if you need a few.

Robotics

For this month's resource sidebar, I thought I'd gather together some of the more obvious sources for hobby robotics. Local clubs, mostly. With a few key suppliers thrown in.

For a number of reasons, low end hobby robotics has never really taken off. First, because those urban-lore "trashcan" and "android" style robot forms are uselessly absurd. One of the favorite tricks in any beginning robotics class is to ask them to design a robot that cleans the dishes after a meal. Only one student out of twenty ever picks up on the fact that *Sears* has been selling these for decades.

A second problem is the mix of skills you'll need. Everything from electronics to new software design to mechanical engineering to kinematics to marketing. Pretty near anything mechanically intensive and made in small experimental quantities for an ill defined market is likely to price itself out of reach. And mass market toy robots have to contend with stiff distributor and retail markups.

The folks at *Mondo-tronics* have long been known for their robotic "muscle wire" products. These have been refined into their new *Electric Pistons*. Actuators with one pound of force and almost one inch of reach. Extension time is two seconds using five watts of power input. Max cycle rate is four cycles per minute.

To me, the *Nitinol* shape memory products certainly have some unique niche uses. But their glacial speeds and high power needs seems to lock them out of ever really hitting the big time. A powerful, fast, and efficient "electric muscle" still remains rather elusive. Which is why all of the big boys still use pneumatics.

HOBBY ROBOTIC RESOURCES

American Science & Surplus
3605 Howard Street
Skokie IL 60076
(708) 982-0870

Appliance
1110 Jorie Blvd CS 9019
Oak Brook IL 60522
(708) 990-3484

Appliance Manufacturer
29100 Aurora Rd #200
Solon OH 44139
(216) 349-3060

Atlanta Hobby Robot Club
PO Box 2050
Stone Mountain GA 30086
(404) 972-7082

Automotive Industries
PO Box 2056
Radnor PA 19080
(215) 964-4876

C&H Sales
PO Box 5356
Pasadena CA 91107
(800) 325-9465

Connecticut Robotics Society
190 Mohegan Drive
West Hartford CT 06117
(860) 233-2379

Dallas Personal Robotics Group
5112 Hardaway Circle
The Colony TX 75056
(214) 625-4454

Design News
8773 S Ridgline Blvd
Highlands Ranch CO 80126
(303) 470-4000

Edmund Scientific
101 E Gloucester Pike
Barrington NJ 08007
(609) 573-6250

Machine Design
1100 Superior Avenue
Cleveland OH 44144
(216) 696-7000

Mondo-tronics Inc
524 San Anselmo Ave #107-20
San Anselmo CA 94960
(800) 374-576

Nashua Robot Builders Club
133-A Haines Street
Nashua NH 03060
(603) 595-5953

Northern New Mexico Robotics
MSD434, LANL
Los Alamos NM 87545
(505) 667-2902

Palo Alto Robotics Club
561 Hyannis Drive
Sunnyvale CA 94087
(408) 749-8815

PARTS - Portland RoboTicS
821 SW 14th
Troutdale OR 97060
(503) 666-5907

PHD Inc
PO Box 9070
Fort Wayne IN 46899
(800) 624-8511

The Robot Group
PO Box 164334
Austin TX 78716
(512) 288-9135

Robotics Society of America
1264 8th Avenue
San Francisco CA 94122
(415) 661-8068

Robotics Society of So California
10471 S Brookhurst Street
Anaheim CA 92804
(714) 535-8161

Rockies Robotics Group
13702 E Lehigh Ave Unit E
Aurora CO 80014
(303) 680-9324

Seattle Robotics Society
PO Box 665
Mill Creek WA 98012
(206) 483-0447

Sensors
174 Concord Street
Peterborough NH 03458
(603) 924-9631

Small Parts
PO Box 4650
Miami Lakes FL 33014
(800) 220-4242

At any rate, Mondotronics is now offering a *Robot Store*. Kinda of a one-stop source for small hobby and educational robots. Their free catalog includes a new robot club directory. Portions of which have been added to our resource sidebar.

Classic robot videos, even.

Let's see. By far the finest robotics source anywhere ever still remains *Small Parts*. Who stock everything a hardware store never heard of.

Three other "must know" low end robotics sources include *C&H Sales*, *American Science & Surplus*, and *Edmund Scientific*. All do have free catalogs on request.

Robot specific magazines seem to come and go. Instead, the industry trade journals which I've found that consistently include the most useful ongoing robotics info in them are *Machine Design*, *Design News*, and *Sensors*. Also useful are *Automotive Industries*, *Appliance* and *Appliance Manufacturer*.

Three new robotic web sites:

robotics.misc
www.robotstore.com
ww.ncc.com/ncc/refaq

A more detailed review of robotics magazines and opportunities appears as RESBN16.PDF on *www.tinaja.com*. Also in my *Resource Bin* reprints.

Your best starting point may be to pick up a meeting or two at one of the regional robotics clubs. Many of these also have newsletters and run competitions.

By the way, I've just picked up a cute little orphan *Armdroid I* student robot. Who is up for adoption. Plus bunches of *PHD* precision industrial automation sliders, rotary actuators, grippers, sensors, and cylinders. All of it big time serious pneumatics. At great prices. Write, email, or give me a call if you have any interest here.

NEED HELP?

Phone or write all your US Tech Musings questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ, 85552
(520) 428-4073

US email: *don@tinaja.com*
Web page: *www.tinaja.com*

New Tech Lit

From *Quality Semiconductor*, a new and free catalog on their *Quick Switch* products. These are useful for network switches, for crossbars, and programmable interconnects. I'm looking at several of these for shared SCSI comm uses.

Hewlett-Packard has a free new *IrDA Data Link Designer's Guide* and kit. Used for the newly emerging wireless infrared comm standard.

Such a deal: The most powerful electron microscope in US is now

NAMES AND NUMBERS

Analog Devices
PO Box 9106
Norwood MA 02062
(617) 329-4700

Burr-Brown
6730 S Tucson Blvd
Tucson AZ 85706
(520) 746-1111

Dallas Semiconductor
4401 Beltwood Pkwy S
Dallas TX 75244
(214) 450-0400

Electronic Servicing
PO Box 12487
Overland Park KS 66282
(913) 492-4857

GEnie
401 N Washington St
Rockville MD 20850
(800) 638-9636

Hewlett-Packard
PO Box 10301
Palo Alto CA 94303
(415) 857-1501

Lindsay Publications
PO Box 538
Bradley IL 60915
(815) 935-5353

National Semiconductor
2900 Semiconductor Rd
Santa Clara CA 95052
(800) 272-9959

Quality Semiconductor
851 Martin Ave
Santa Clara CA 95050
(408) 450-8063

Shallco
308 Components Drive
Smithfield NC 27577
(919) 934-3135

Synergetics
Box 809
Thatcher AZ 85552
(520) 428-4073

Xicor Inc
1511 Buckeye Dr
Milpitas CA 95035
(408) 432-8888

offered for *remote* experiments. Via the Internet. To submit a proposal, you can contact…

http://ncem.lbl.gov/ncem.html

Two new reprints from *Lindsay Publications*. The first one is *The Boy Electrician* by Alfred Morgan. It was originally published in 1940. On making your own telephones, radios, batteries, and induction coils.

I particularly like all of the lucid instructions and the super clear tech illustrations. When compared against the glitzy schmaltz of the latest vapid computer magazines, effective tech communications sure seems to have gone downhill lately.

The second is *Strange Stories from Electrical Experimenter Magazine*. A thinner reprint having some original Tesla and Gernsback oddments in it. But any "lost" technology you'll find here is best left that way.

Great reading, though.

Lindsay has many more titles on old turn-of-the-century machine shop techniques, antique radio, and texts on how to make just about anything.

Free catalogs are offered.

Industry insider publications this month include *Multimedia Producer*, *Inter@ctive Week*, *Emf-Emi Control*, and the *MFP Report*. The latter is on *multifunction peripherals* that can combine copying, printing, fax, and document scanning.

For many individuals most of the time, patents are virtually *certain* to end up a total loss of time, energy, money, and sanity. Find out why in my *Case Against Patents* package. Along with lots of tested and proven real-world alternatives. Also a big reminder that I recently bought an *entire* community college electronics department at auction and have a freebie surplus sale flyer for you.

As usual, please carefully read our *Names & Numbers* and our *Robotics Resources* sidebars before you dial our no-charge US technical helpline. Immediate help, along with reprints and preprints of my columns appear on *www.tinaja.com*.

The master Synergetics *Names & numbers* directory has recently been uploaded. It includes 3000+ sources of info hard to find elsewhere.

I have also just added a lot more *Basic Stamp* support, lots more on Acrobat, more magic sinewaves, and all sorts of annotated hot inks. We also do now provide several *Scott Edwards* columns plus the *Society of Amateur Scientists* link. ✥