SPECIAL SPEAKER SECTION

The Sound Strobe

With this simple diagnostic tool, you can test the sound of your loudspeakers. . . without hauling them to the lab.

By Dennis Colin

Listening to these pulse signals, with six selectable spectrum shapes, is very revealing of loudspeaker time smear (driver "hangover," crossover misalignment, cabinet diffraction, and so on), frequency response colorations (particularly from resonances), and room effects such as discrete echoes, standing-wave bass modes, and acoustic colorations in general. You can hear quickly, and with detailed clarity, the speaker's degree of image focus, transient precision, and tonal neutrality.

OVERVIEW

Six pulse shapes are generated with a pulse repetition frequency (PRF) of 0.5-41.2Hz (see unit in **Photos 1–4**). The lower (rhythmic) rates allow hearing detailed decay patterns, while the audio rates (41.2Hz is the low "E" on a 4-string bass) provide harmonically-rich tones very sensitive to response and coherence anomalies. The selectable spectral distributions range from linear to non-resonantly shaped, allowing a focus on various frequency ranges. The impulse waveform and a linear ramp sawtooth are also provided at additional outputs, useful for oscilloscope triggering and X-Y plots.

The compact (8¼″ × 5¾″ × 3½″) low cost generator is powered by two rechargeable 9V batteries or an AC line "wall wart" (**Photos 5** and **6**); the batteries will power the unit for about 10 hours/charge.

APPLICATIONS

Listening to test signals is, of course, no substitute for music evaluation. Rather, these wideband coherent-transient pulses serve as an auditory diagnostic tool; repeatable signals allow sonic identification of a wide variety of speaker and room anomalies. The time-coherent nature of the pulses allows you to simultaneously hear and distinguish both the direct speaker output's image focus and a plethora of room effects. Walking around the room, you can identify reflective surfaces contributing colorations, discrete echoes, and so on.

An additional application is peak power testing for distortion and compression: with the short-duration (14.5µs) impulse waveform, you can even test a tweeter at 1kW peak, because even at the maximum PRF of 41.2Hz the average power is only 0.5W.

WAVEFORM DATA

Figure 1 shows the six waveforms, spectral distributions, pulse widths, and RMS to peak voltage ratios at two PRFs, 5Hz, and 40Hz. Squaring these

PHOTO 1: Sound Strobe front .

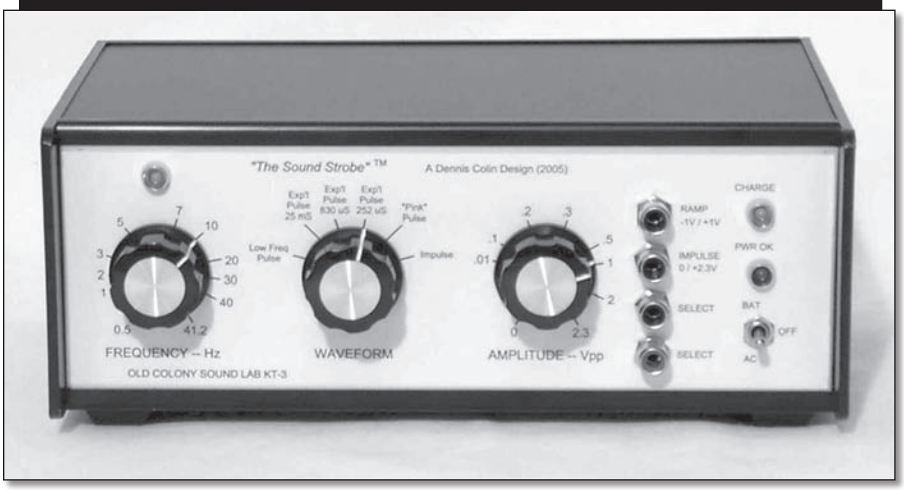
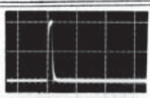
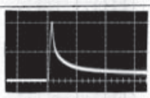
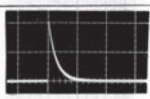
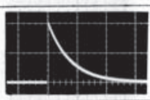
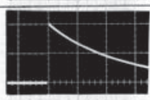
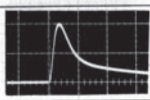


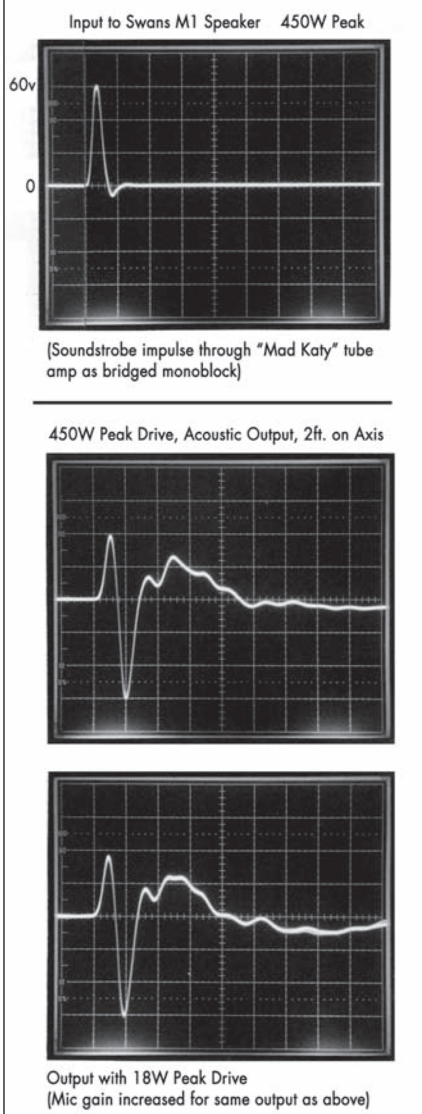
PHOTO 2: Rear view of unit.

FIGURE 1: Waveform data.

WAVEFORM (NOTE DIFFERENT TIME SCALES)		SPECTRUM 20 Hz ↓ (PER OCT. BASIS) 20 KHz ↓	SLOPES dB/OCT	PULSE WIDTH @ 50% VPK	VRMS/VPK PRF=40Hz	VRMS/VPK PRF=5Hz
	IMPULSE 100µS/div		+3	14.5µS	0.022	0.008
	"PINK PULSE" 100µS/div		0	20µS	0.033	0.012
	EXP'L PULSE TC=252µS 1mS/div	632 Hz	+3, -3	175µS	0.075	0.026
	EXP'L PULSE TC=830µS 1mS/div	192 Hz	+3, -3	575µS	0.122	0.043
	EXP'L PULSE TC=25mS 10mS/div		-3	17.5mS	0.493	0.248
	LOW FREQ. PULSE 5mS/div	200 Hz	0, -15	3.8mS	0.342	0.128

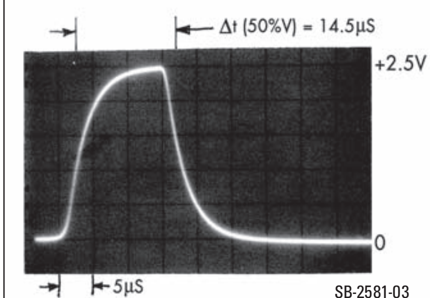
SB-2581-01

FIGURE 2: High power impulse testing of speaker.



SB-2581-02

FIGURE 3: Impulse.



SB-2581-03

ratios gives the ratios of average to peak power delivered to the speaker, useful for ensuring safe high-peak-power testing for compression and distortion. **Figure 2** shows an example of this high power testing. The impulse signal was amplified by "Mad Katy" (**Photo 7**), a 125W per channel stereo tube amp I designed. Driven to just below clipping in bridged monoblock mode, a peak impulse power of 450W was delivered to a Swans M1 speaker (average impedance about 8Ω). This excellent mini-monitor with ribbon tweeter (which I reviewed in *SB* 3/99) had no problem handling the 450W peak impulse, as shown by the very small change regarding the response with 18W peak power.

The 450W peak impulse, at the 20Hz PRF I used, produced an average power of only 0.11W. Perceived loudness was closer to the 113dB peak SPL than the 77dB average SPL. The sound was very "snappy," similar to that of electric sparks. It was very easy to distinguish the direct speaker output (crisp "snaps" with almost no tonal color) from the room sound (an enveloping "ocean" of thousands of pulse harmonics with tonality sustained by standing waves, and discrete pulse reflections originating from localizable reflecting surfaces).

When I moved about the room, the reverberation became a massive 3D "chorus effect" of moving pulses and changing overtone patterns, yet the speaker's directly-radiated impulses maintained the precise focus and tonal neutrality that I praised the Swans M1 for in the review.

The spectrum of a single impulse (for practical purposes, a unipolar pulse of shorter duration than a quarter cycle of the highest frequency of interest) is continuous and flat, with constant bandwidth (BW) analysis; that is, there's equal power per Hz BW across the band.

However, the ear analyzes on a frequency-proportional basis; that is, power per octave (or fraction thereof). Therefore, a flat *per-Hz* spectrum signal, such as an impulse or white noise, is perceived as having a 3dB/octave upward slope; that's why white noise sounds thin and "hissy." Conversely, pink noise sounds flat, spectrally balanced; its spectrum slopes downward (-3dB/octave) on a per-Hz analysis, but is flat on a per-octave basis. The spectra in **Fig. 1** are with per-octave analysis, the way we hear.

SPECIFIC WAVEFORM DESCRIPTIONS

1. Impulse

Figure 3 shows this on an expanded (5µs/div) time scale; pulse width at 50% Vpeak is 14.5µs; 10-90% rise and fall times are about 6µs. Compared with an ideal impulse, the spectrum is -1dB at 20kHz, and –3dB at 30kHz.

The sound (on a very neutral and coherent speaker) is very "snappy" and colorless like a small electric spark, but not as "sizzly bright"—that's because a small (<¼″) spark radiates an acoustic doublet waveform: a differentiated impulse with spectrum sloped up 6dB/octave with reference to an impulse. (Lightning, a very big spark, radiates nearly a step function sound wave, with bass to below 1Hz.)

The impulse, with its linear upward-sloping spectrum (to the ear), is best for hearing tweeter reflections, diffraction, and other anomalies of time coherence and HF tonal neutrality.

2. "Pink Pulse"

Figure 4 shows this on a range of time scales. This waveform has several interesting properties:

a) A flat spectrum on a per-octave basis (as the ear analyzes), like pink noise (hence the name).

b) The decay looks similar over a wide range of time scales.

FIGURE 4: "Pink pulse;" band limited, -3dB re ideal at 30kHz.

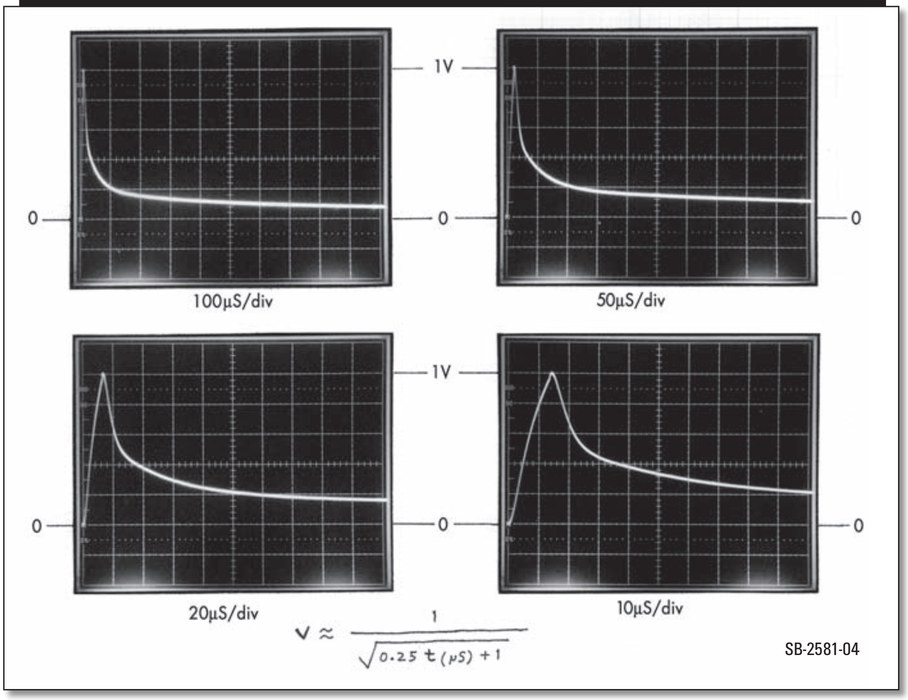
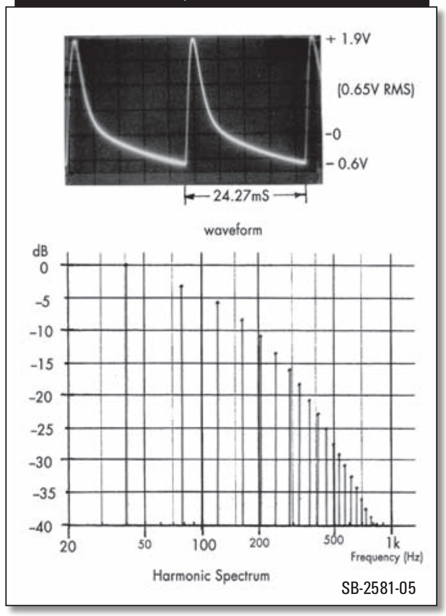


FIGURE 5: LF pulse at 41.2Hz PRF.



c) An ideal pink pulse (infinite BW) would initiate with a jump to infinity, and decay inversely proportional to the square root of time. The pulse shown has a -3dB rolloff at 30kHz.

d) With constant BW (e.g., per Hz) spectral analysis, such as is used in Laplace transforms, the (ideal) pink pulse is the only non-repeating waveform whose shape is identical to that of its spectrum: the spectral amplitude is proportional to 1/√frequency; that is, a slope of –3dB/octave with constant BW analysis (flat to the ear).

The sound has a sharp attack like the impulse, but has "full-bodied" midrange and bass, rather than the predominant HF "snap." It's basically a tonally-neutral full-band precision "click," extremely revealing of time and tonal response anomalies across the audio spectrum. Only with the very best speakers will this pulse maintain its pristine transient impact and lack of tonality.

3. Exponential pulse, 252μs time constant (TC)

As the sonically-perceived spectrum in **Fig. 1** shows, this pulse has a broad (non-resonant) peak at 632Hz, the logarithmic center of the audio band. This pulse doesn't sound "colored," but the midrange emphasis serves to best reveal midrange response anomalies, while maintaining enough perspective of lower and higher frequencies. The sound (on a good speaker, of course) could be described as a "fat click."

4. Exponential pulse, 830μs TC

This is similar to the previous pulse, but with the non-resonant peak at 192Hz. It's generated by 1st-order highpass filtering a step pulse, rolling it off below 192Hz (-3dB point). It's useful for hearing the step response of small speakers, without subjecting them to the excessive bass power of an unfiltered step pulse. It's also useful for evaluating mid-bass coherence and neutrality.

5. Exponential pulse, 25ms TC

This is basically a raw step pulse, the 25ms TC decay being the result of a 6Hz 1st-order LF rolloff. It's useful for evaluating full-band coherence and bass impact of large speakers. Caution: it's tempting to turn up the volume enough to feel the impact, rattle the walls, and so on, but with a high-powered amp, woofer damage is quite possible.

6. Low frequency pulse

As the spectrum in **Fig. 1** shows, this pulse doesn't have the rising deep bass energy of the previous pulse, but it's strongly filtered above 200Hz. The sound could be described as a nonresonant "thump," but sharper in precision than that word implies. The spectrum (again, to the ear) is flat from about 20-100Hz. This pulse is useful for hearing bass clarity, impact precision, and tonal neutrality.

Figure 5 shows the waveform and harmonic spectrum when this pulse is repeated at an audio rate, 41.2Hz (the low "E" on a 4-string bass). The rich but smoothly rolled-off harmonic content produces a pleasing, string-like bass tone that serves as a repeatable test of bass coherence and neutrality.

OSCILLATOR

U1A (latching comparator or "hysteretic switch") and U1B (integrator) form a linear-ramp sawtooth oscillator (**Fig. 6a**). Without D1 and R10, the output at U1B pin 7 would be a symmetrical triangle wave. But D1 conducts when U1A pin 1 is positive, producing a rapid fall time (13µs) at pin 7. Pot R32, R9, R11, and C1 determine the ramp charging time, and therefore the oscillator frequency.

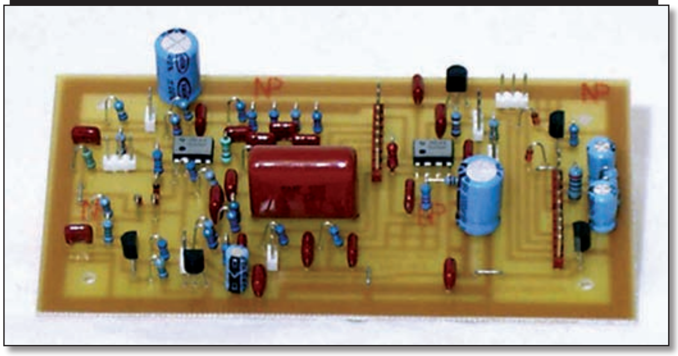


PHOTO 3: Sound Strobe PCB.

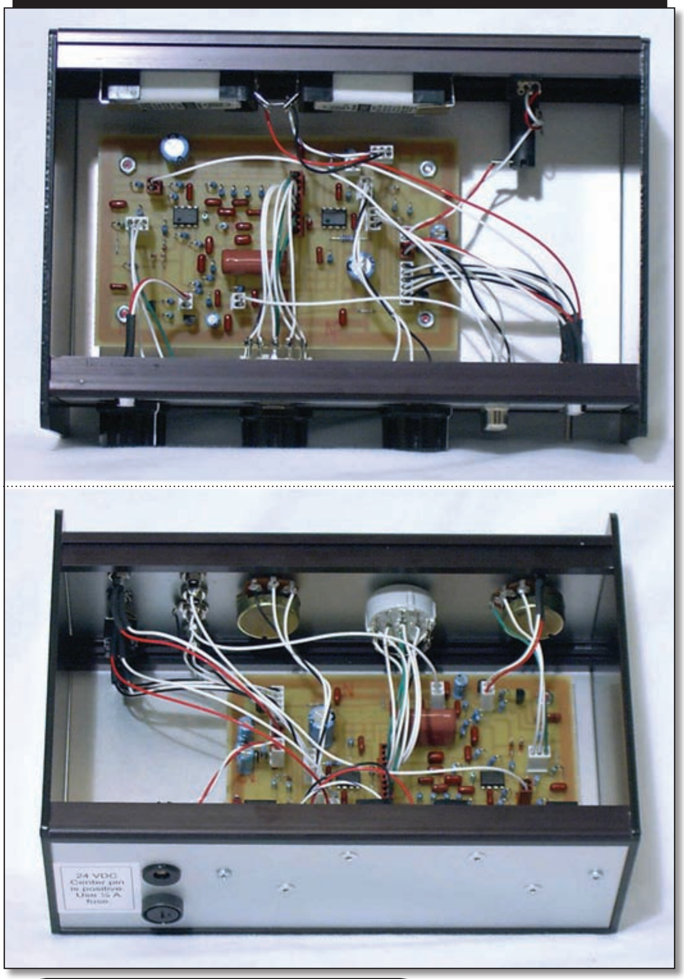


PHOTO 4a, b: Inside top panel.

The voltage at pin 1 pulses positive for about 13µs, and stays negative for the rest of the cycle. This waveform, through D2, R26, R27, and C16, produces the impulse signal selectable by S2. The pin 1 pulse also drives the circuitry from D3 to Q1, Q2, which flashes the green LED 1 (140mA for about 100µs, 1mA maximum average DC) in sync with the output pulses.

PINK PULSE SHAPER

The ramp reset step from U1 pin 7 has the step function's –6dB/octave spectrum with constant BW analysis, but –3dB/octave slope to the ear. So this is equalized with a +3dB/octave slope to achieve the desired flat auditory spectrum. Note: the impulse waveform could have been used with a –3dB/octave EQ, but for the same peak voltage limit, the impulse has much less energy.

R4 through R8 and C2 through C5 comprise a –3dB/octave impedance network, accurate within ±0.5dB from 10Hz–25kHz. Connected between the sawtooth step and the output op amp U2B inverting input pin 6 (when selector S2 is in position 5), the network's –3dB/octave impedance/frequency slope adds an upward +3dB/octave slope at the out-

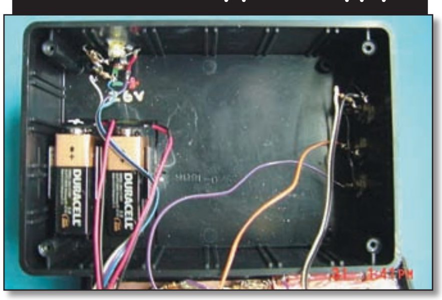


PHOTO 5: Battery power supply.

PHOTO 6: AC line "wall wart."

PHOTO 7: "Mad Katy" amp used for impulse power test.

put (U2 pin 7). **Figure 7** shows the 1kHz square wave (from an external generator) response of the shaping circuit.

EXPONENTIAL PULSES

C6, 7, and 8, with R14, 15, form first-order high-pass filters, determining the exponential decay time constants. While with constant BW analysis such pulses have a flat spectrum up to the HP filter corner frequency, then slope-down (-6dB/octave), to the ear the spectrum peaks at this frequency as shown in **Fig. 1**.

LF PULSE

The sawtooth wave is first sloped upward (+3dB/octave) by C9, 10 and R19, 20, 21, to produce a flat auditory spectrum; then it's low-pass-filtered above 200Hz by R22, 23, C11, 12, and C13, R18. The net LP filtered spectrum has a slope of about –15dB/octave. Consisting of cascaded first (and half)-order networks, the rolloff is non-resonant (sonically uncolored).

Note that in **Fig. 5** (harmonic spectrum of LF pulse at a PRF of 41.2Hz),

FIGURE 6a: Sound Strobe schematic.

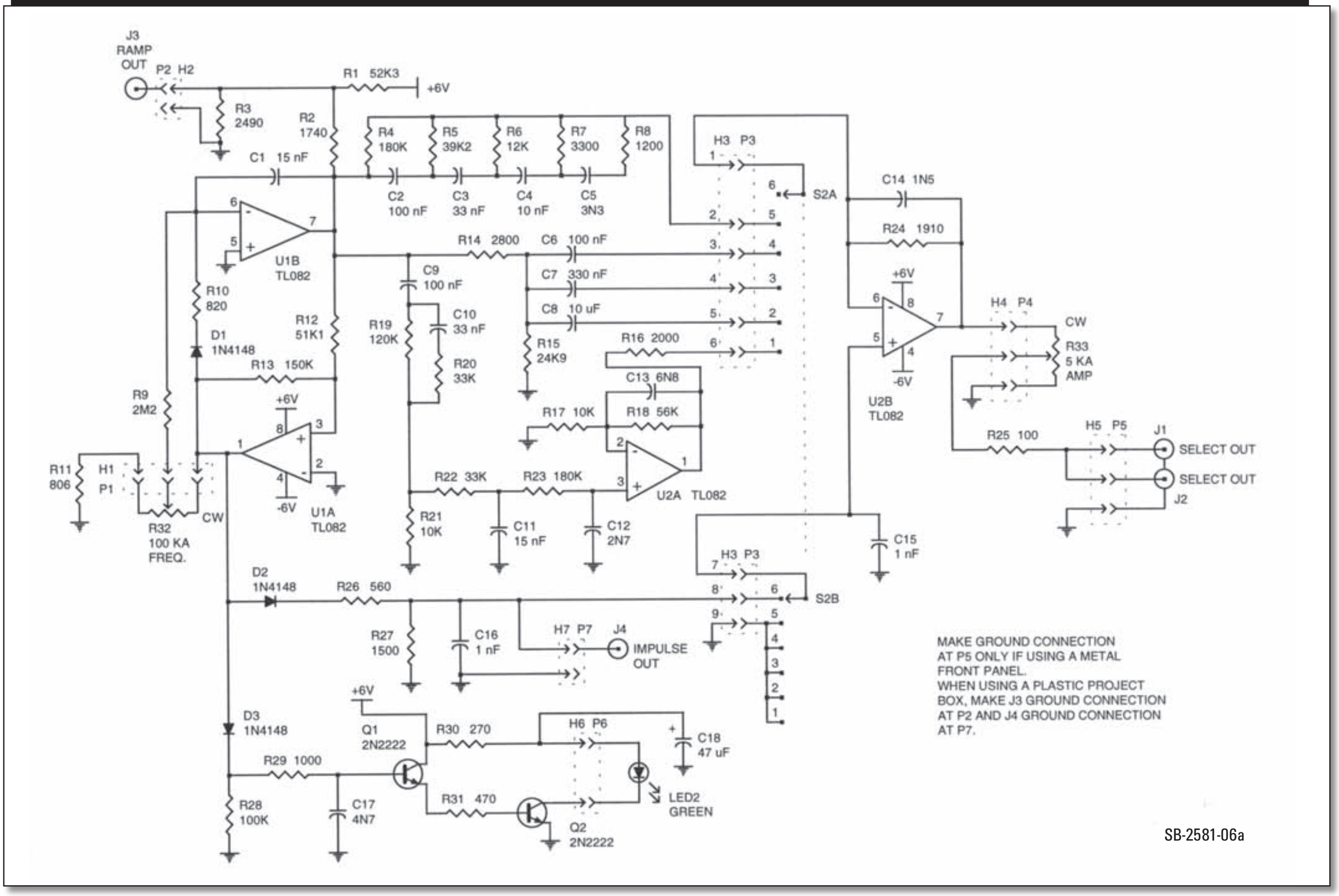
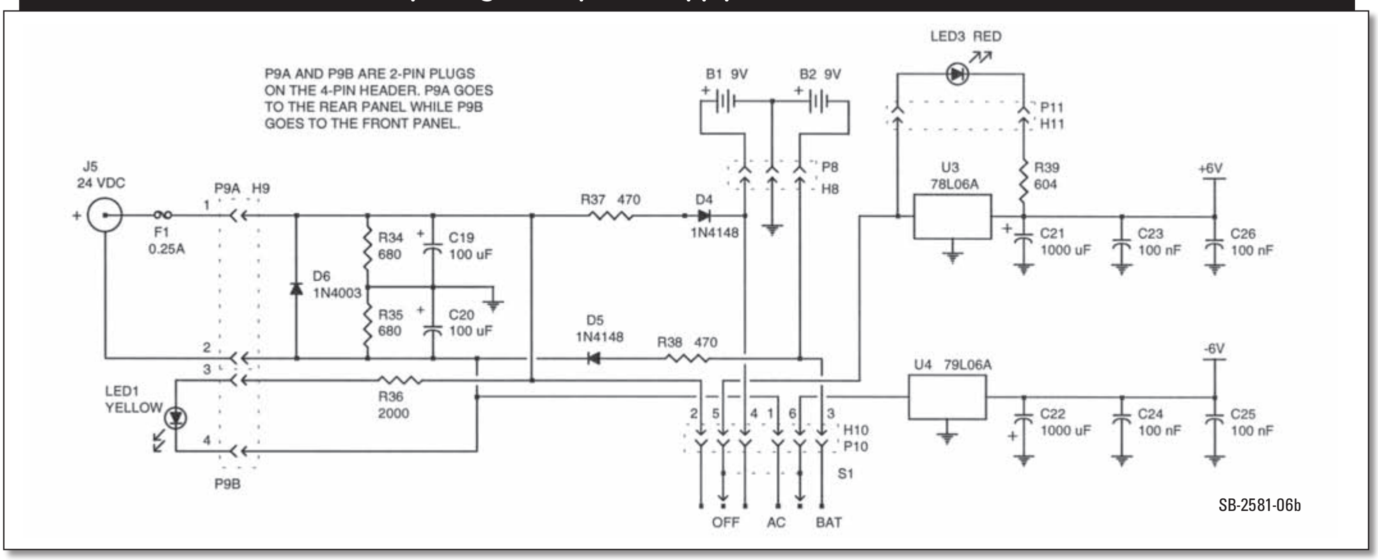


FIGURE 6b: Schematic of battery charger and power supply.



the first few harmonics decrease in amplitude by about 3dB/octave, while the single-pulse spectrum in **Fig. 1** is flat below 200Hz. This is because discrete spectral lines' amplitudes aren't subject to analysis bandwidth, unlike a spectral continuum such as noise or single events. But there's no contradiction: the harmonics (below the 200Hz filtering) *do* roll off at about 3dB/octave, but as frequency doubles, the *number* of harmonics *per octave* doubles, increasing the power per octave by a slope of 3dB/octave. So the net power/octave that the ear analyzes is approximately constant (below the 200Hz LP filtering).

SELECTOR SWITCH S2

In positions 1 through 5 (all waveforms except impulse), the output op amp's non-inverting input is grounded by S2B, and the negative-going sawtooth step's shaped pulses are inverted for a positive-going output from U2B.

In S2 position 6 (impulse output), the impulse is fed to U2B non-inverting input, while S2A opens

PARTS LIST

Reference	Value	Description	Manufacturer
R1	52K3	1%, ¼W, metal film	Mouser 271-52.3K
R2	1740	1%, ¼W, metal film	Mouser 271-1.74K
R3	2490	1%, ¼W, metal film	Mouser 271-2.49K
R4, R23	180K	1%, ¼W, metal film	Mouser 271-180K
R5	39K2	1%, ¼W, metal film	Mouser 271-39.2K
R6	12K	1%, ¼W, metal film	Mouser 271-12K
R7	3300	1%, ¼W, metal film	Mouser 271-3.3K
R8	1200	1%, ¼W, metal film	Mouser 271-1.2K
R9	2M2	1%, ¼W, metal film	Mouser 271-2.2M
R10	820	1%, ¼W, metal film	Mouser 271-820
R11	806	1%, ¼W, metal film	Mouser 271-806
R12	51K1	1%, ¼W, metal film	Mouser 271-51.1K
R13	150K	1%, ¼W, metal film	Mouser 271-150K
R14	2800	1%, ¼W, metal film	Mouser 271-2.8K
R15	24K9	1%, ¼W, metal film	Mouser 271-24.9K
R16	2000	1%, ¼W, metal film	Mouser 271-2K
R17, R21	10K	1%, ¼W, metal film	Mouser 271-10K
R18	56K	1%, ¼W, metal film	Mouser 271-56K
R19	120K	1%, ¼W, metal film	Mouser 271-120K
R20, R22	33K	1%, ¼W, metal film	Mouser 271-33K
R24	1910	1%, ¼W, metal film	Mouser 271-1.91K
R25	100	1%, ¼W, metal film	Mouser 271-100
R26	560	1%, ¼W, metal film	Mouser 271-560
R27	1500	1%, ¼W, metal film	Mouser 271-1.5K
R28	100K	1%, ¼W, metal film	Mouser 271-100K
R29	1000	1%, ¼W, metal film	Mouser 271-1K
R30	270	1%, ¼W, metal film	Mouser 271-270
R31	470	1%, ¼W, metal film	Mouser 271-470
R32	100K	Pot, audio taper	Mouser (Alpha) 31VJ501
R33	5000	Pot, audio taper	Mouser (Alpha) 31VJ305
R34, R35	680	1%, ½W, metal film	Mouser 273-680
R36	2000	1%, ½W, metal film	Mouser 273-2K
R37, R38	470	1%, ¼W, metal film	Mouser 271-470
R39	604	1%, ½W, metal film	Mouser 273-604
C1, C11	15nF	5%, 50V, polyester film	Digi-Key (Panasonic) P4584
C2, C6, C9, C23, C24, C25, C26	100nF	5%, 50V, polyester film	Digi-Key (Panasonic) P4525
C3, C10	33nF	5%, 50 V, polyester film	Digi-Key (Panasonic) P4569
C4	10nF	5%, 50V, polyester film	Digi-Key (Panasonic) P4582
C5	3n3	5%, 50V, polyester film	Digi-Key (Panasonic) P4557
C7	330nF	5%, 50V, polyester film	Digi-Key (Panasonic) P4549
C8	10µF	10%, 100V, polyester film	Digi-Key (Panasonic) EF1106
C12	2n7	5%, 50V, polyester film	Digi-Key (Panasonic) P4556
C13	6n8	5%, 50V, polyester film	Digi-Key (Panasonic) P4561
C14	1n5	5%, 50V, polyester film	Digi-Key (Panasonic) P4553
C15, C16	1nF	5%, 50V, polyester film	Digi-Key (Panasonic) P4551
C17	4n7	5%, 50V, polyester film	Digi-Key (Panasonic) P4559
C18	47µF	25V, radial electrolytic	Mouser (Xicon) 140-XRL25V47
C19, C20	100µF	25V, radial electrolytic	Mouser (Xicon) 140-XRL25V100
C21, C22	1000µF	25V, radial electrolytic	Mouser (Xicon) 140-XRL25V1000
U1, U2	TL082	Dual opamp, 8-pin DIP	Mouser (TI) 595-TL082ACP
U3	78L06A	+6V regulator, TO-92	Digi-Key (Panasonic) AN78L06
U4	79L06A	–6V regulator, TO-92	Digi-Key (Panasonic) AN79L06
D1, D2, D3, D4, D5	1N4148	Silicon diode	Mouser 1N4148MSCT
D6	1N4003	Silicon diode	Mouser 1N4003MSCT
LED1	Yellow LED Charge-on indicator		Lumax SSI-LXR1612YD (Digi-Key 67-1149)
LED2	Green LED Freq indicator		Lumax SSI-LXR1612GD (Digi-Key 67-1148)
LED3	Red LED Low-battery indicator		Lumax SSI-LXR1612ID (DigiKey 67-1147)
J1, J3, J4	Female, panel mount RCA, black		DGS (Mouser 161-1052)
J2	Female, panel mount RCA, red		DGS (Mouser 161-1053)
J5	2.5mm male, insulated, panel mount, power input connector		DGS (Mouser 163-4303)
P1, P4, P5, P8	3-pin shell with terminal pins		Molex WM2012
P2, P6, P7, P9A, P9B, P11	2-pin shell with terminal pins		Molex WM2011
P3	9-pin shell with terminal pins		Molex WM2018
P10	6-pin shell with terminal pins (39) terminal pins for the Molex shells		Molex WM2015 Molex WM2200
H1, H4, H5, H8	3-pin male header		Molex WM4001

(continues →)

the inverting input. Thus, U2B acts as a voltage follower for the (positive) impulse waveform.

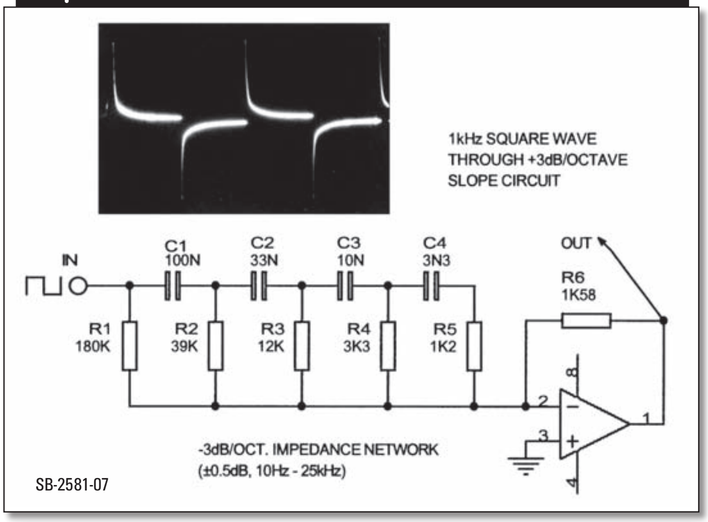
C14 and C15 serve to attenuate ultrasonic pulse components (extending to above 100kHz).

POWER SUPPLY (FIG. 6b)

S1 selects "AC," "off," or "BAT." The suppy selected is regulated to ±6V by U3, U4, and so on. Batteries B1, B2 (9V NiCd) are charged with a tapered current averaging 10mA.

LED1 (yellow) indicates AC power.

FIGURE 7: 1kHz square wave through +3dB/octave slope circuit.



PARTS LIST (cont.)

H2, H6, H7, H11	2-pin male header	Molex WM4000
H3	9-pin male header	Molex WM4007
H9	4-pin male header	Molex WM4002
H10	6-pin male header	Molex WM4004
	(Headers, shells and terminal pins are available from Mouser, Digi-Key, and others.)	
S1	DPDT miniature toggle switch	Digi-Key (Carling) 432-1149
S2	Rotary switch, 2-pole, 6-positions,	
	break-before-make	Mouser (Lorin) 105-14572
	Enclosure, 8 × 5 × 3″	Sescom MC-6A
	Circuit board	
	Front panel	Metalphoto of Cincinnati
	Stick-on label for rear panel	TDL M121R
	(3) knobs	Mouser (Eagle Plastics) 45KN017
	Panel mount 5mm fuse holder	Mouser (Littlefuse) 576-03455LS1H
	5mm fuse, 0.25A	Digi-Key (Wickmann) WK1035
	(2) battery holders	Mouser (Keystone) 534-1295
	(2) battery retaining clips	TDL M401BRC
	(4) aluminum pop rivets, 1/8″dia × 1/8″grip (to attach battery holders to rear panel)	
	(2) 4-40 × 5/16″machine screws	Mouser H343
	(4) 4-40 × 5/8″machine screws	Mouser H348
	(2) #4 lock washers	Mouser H236
	(6) 4-40 hex nuts	Mouser H216
	(4) 3/8″long nylon spacers, tapped 4-40	Mouser (Eagle Plastics) 561-L4.375
	(4) Stick-on plastic feet for enclosure bottom	Mouser (3M) 517-SJ-5023BK
	(13′) #24 AWG stranded wire	
	(2) 9V rechargeable NiCd batteries	JDR NB9V or equal
	Wall DC power supply, 24V DC at 100mA	Mouser 412-124013

LED3 (red), labled "Pwr on," indicates both that and sufficient charge of batteries is used. Note the connection of LED3 differentially across regulator U3, biased by R39 to glow only with sufficient positive battery charge; and because the positive battery (B1) has a slightly higher discharge rate than the negative one (B2)—about 12mA versus 10mA—than LED3 indicates satisfactory charge of both batteries.

Note that the current through LED3 contributes to the positive load current; therefore it is "free." Also, its brightness varies with charge level, serving as a "fuel gauge."

USING THE SOUND STROBE

The pulses provided can be very revealing of transient and tonal reproduction characteristics, but first you must know what the pulses *should* sound like. The short answer is "as sharp, spatially focused, and non-tonal (uncolored) as possible." Think of hearing an electric spark—there's no tonality, but an immediate "Snap!" that you can locate to within inches from across the room. It's so precisely focused that you instinctively jump to look for it.

The best full-range speakers, electrostatics, planar magnetics, or small cones, can come close to this precision. Many multi-way speakers fall short, and the Sound Strobe pulses are heard spread out in time and space. Admittedly this is unfair; we listen to music, not electronic pulses (except for synthesizers); and (at least acoustic) music doesn't have transients nearly as sharp as electronic impulses. But if you aren't completely satisfied with your speakers (present or contemplated), then these test pulses can help you diagnose and improve their sonic fidelity.

The longer answer to knowing what to listen for is this: I strongly recommend playing all six pulses on the very best speakers available, from friends, willing retailers, and so on. I also recommend good headphones, with their excellent time coherence. Of course, their lack of room acoustics makes for an unfair comparison with speakers; however, the pulses' sharp transient nature, coupled with the Haas (precedence) effect, allows you to distinguish a speaker's direct output from the room reverberation.

It's also informative to listen to the pulses on a wide variety of speakers, from the best to the worst available. Correlating the pulse sound with music will then build up an "experience base" of various transient, focus, and tonal anomalies. Then you can use the repeatable high-resolution pulses to quickly identify problem areas by direct listening (unlike trying to interpret electronic measurements), and without the immense variability of musical sounds.

Of course, the goal is to reproduce this musical variety with the utmost clarity and fidelity. With a modest "experience base," the Sound Strobe can be a useful tool for that goal. Plus, it's fun to experiment with—you'll hear a very intriguing array of speaker and room (distinguishable) pulse-response sounds that can directly relate to the reproduction of music.

I'd like to thank Ron Tipton (*info@tdl-tech.com*) for his excellent packaging, board layout, and finetuning for production. aX

The Sound Strobe is available in kit or assembled units from Old Colony Sound Lab, PO Box 876, Peterborough, NH 03458, 888-924-9465, e-mail: custserv@audioXpress.com