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What Makes a Good Solid-State Amplifier for the Contester — Part 2

Automatic Level Control (ALC)

Some form of ALC should always be used to prevent driving the linear amplifier into the peak-flattening range — beyond its linear PEP capability. Excessive drive causes high IMD (splatter) on both sides of the signal[1].

The ALC output feeds back a dc control voltage to gain-controlled IF stages in the exciter. This voltage is proportional to the amplifier power output. The ALC voltage is usually negative-going; the higher the voltage, the lower the exciter output (drive power). The purpose of the ALC is twofold: (1) to limit the amplifier output to a preset level without causing distortion, and (2) to reduce drive when the amplifier's protective subsystem detects an out-of-limits condition.

During normal amplifier operation, the controller derives the ALC voltage from the forward-power signal supplied by the reflectometer between the LPF output and the auto-tuner input. This is fundamentally different from the ALC derivation method used in most tube amplifiers, in which the ALC voltage is usually derived from PA-stage grid current. In a tube amplifier, the ALC prevents overdrive by reducing the RF drive at the onset of grid current.

In general, the initial ALC attack time should be as short as practicable, to minimize overshoot. For SSB service, the ALC release time should be longer than 140 ms (the reciprocal of the syllabic rate) to prevent the ALC from "riding" on voice peaks. For CW, the ALC release time should be longer than the longest element at the slowest keying rate, to ensure that the ALC loop does not follow keying. Typical values for voice-circuit use are an attack time of 1 to 2 mS, and release time of 0.25 to 2 seconds[2].

In radiotelegraph (CW) service, the attack time should be even shorter, if possible, so as to minimize "thump" at the leading edge of the initial element due to ALC overshoot.

It is essential that the ALC attack and release time constants be chosen to ensure that the ALC loop does not follow the baseband or keying envelope and "modulate" the transmitted signal. Such spurious "modulation" can give rise to severe IMD and spurious products on both sides of the signal.

As mentioned, IMD degrades quite rapidly, if the design power rating is exceeded (IMD3 rises by 3 dB, and IMD5 by 5 dB, for every 1 dB increase in P_o over rated output.) To avoid this, the operator should adjust the ALC at the amplifier to hold the power output to the rated level. ALC should be adjusted in RTTY or CW mode, with the exciter's RF output control initially set at 100% (or 100 W, whichever is lower). The exciter's output should then be backed off to the point where the ALC just levels the amplifier's output at the design rating.

Upon detecting any anomalous condition, the controller will also develop sufficient ALC voltage to reduce the drive to a safe level. For example, the reflected-power signal generated by the reflectometer reports a load mismatch to the controller, which in turn folds back the drive via the ALC line.

Proper connection and adjustment of the ALC is absolutely mandatory when using a solid-state amplifier. The ALC line is the amplifier's first line of defense. Failure to properly configure ALC will place the costly RF power devices (and other components) at risk of destruction.

Typically, a modern solid-state amplifier provides a negative-going ALC voltage in the range of 0 to –10 V. The ALC source impedance is approximately 10 kΩ. At the amplifier's rated output, the ALC voltage is typically –4 V. Never connect a solid-state amplifier to an exciter that is not equipped with a compatible ALC input.

With the ALC correctly adjusted according to the amplifier manufacturer's instructions, the exciter's drive power control should be set just at the point where the amplifier delivers nominal power output, and no higher. This will minimize "ALC compression" and prevent overdrive in the unlikely event of ALC failure.

Low-Pass Filter

The low-pass filter (LPF) module is the

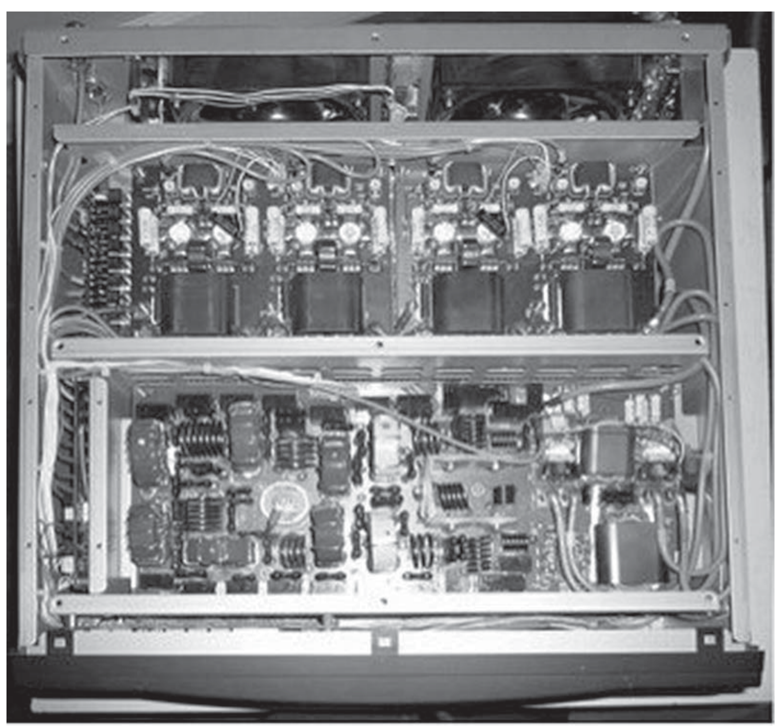

Figure 1 — Yaesu Quadra interior, showing the power amplifier (top) and low-pass filter (bottom) modules.

Table 1 — Current HF and HF + 6 Meter Solid-State Amplifiers.

Brand	Model	Bands	Devices	V_{DD}	Pwr out W	Drive W	ATU	PSU	Price $	Remarks
Icom	IC-PW1	HF+6m	8 MRF50	48V	1000	≈30	Y	SMPS	4900	Auto w/Icom
Yaesu	Quadra		8 MRF150	48V	1000	≈ 60	Y		4300	Auto w/Yaesu[1]
Acom[2]	600S		2 MRFE6VP6300H	48V	600	≈ 20	N		2800	Auto via CAT
	1200S		2 BLF188	48V	1299	≈ 50	N		3500	Auto via CAT
Elecraft	KPA500		2 VRF2933	60V	500	≈ 30	KAT500	Linear	2400	CAT/RF sense
	KPA1500		2 BLF 188	60V	1500	≈ 50	Y	SMPS	6000	
SPE	1.3K-FA		1 LDMOS	50V	1300	≈ 45	OPT		4300[3]	CAT/RF sense
	1.5K-FA		1 LDMOS	60V	1500	≈ 50	Y		5000	
	2K-FA		6 MRF151G	50V	2000	≈ 70	Y		6700	
Flex	PG-XL		2 MRF1K50H	50V	2000	≈ 50	OPT		7000	CAT/Ethernet
Hilberling	HPA-8000A54		1 LDMOS	50V	1000	≈ 50	Y		6600	Auto via CAT
Palstar	LA-1K		2 MRFE6VP5600H	50V	1000	≈ 50	N		3800	RF sense
Ameritron	ALS-600	HF	4 MRF150	50V	600	≈30	N	Linear	2100	EB-104
	ALS-1300		8 MRF150	50V	1200	≈50	N	SMPS	2900	2 X EB-104

Notes: 1. RF sense with non-Yaesu exciter
2. No ALC output
3 With ATU. $700 less w/o ATU.

next component in the RF signal path. As mentioned, the LPF box is a shielded enclosure containing a bank of band-switched low-pass filters. These filters are usually Chebyshev networks, offering high attenuation and a steep roll-off near the cut-off frequency. They are designed to suppress harmonics and spurious emissions to levels required by radio regulations, typically –46 dBc or lower (see Figure 5).

The filters are implemented using air-wound and ferrite-cored (toroidal) inductors, and low-loss, high-Q, high-current capacitors (e.g., silver mica). One filter is provided per frequency band or range, and the filters are switched in and out of the signal path via miniature high-speed sealed relays. Cooling air is passed through the LPF box to remove heat caused by RF losses. The filter insertion loss is typically 0.5 to 1 dB in the passband.

Auto-Tuner

Some solid-state HF amplifiers are fitted with an internal auto-tuner. This is typically a T-network, with capacitive series arms and an inductive shunt arm. The capacitive elements are motor-driven air-variable capacitors or relay-switched fixed capacitors, while the inductive element is a combination of air-wound and ferrite-cored coils, with relay-switched taps. A reflectometer at the tuner input (and, in some designs, a phase comparator measuring the phase angle between the tuner input and output) signal an "optimum match" condition to the controller when reflected power is minimal and the input/output phase shift is exactly 180°. This stops the capacitor drive motors (see Figure 1).

Another approach utilizes a reflectometer and a return-loss bridge at the auto-tuner input. The controller initially reads the reflectometer for coarse tuning, then switches the return-loss bridge into the tuner-input signal path for fine tuning. The capacitor drive motors are stopped at the point of maximum return loss.

In a tuner employing fixed, relay-switched C and L elements, the "optimum match" condition stops the search routine and the controller sets the relays to the tuning solution.

In some amplifier designs, the controller either bypasses the PA stage or inserts a 20-dB attenuator in the PA output signal path, to minimize interference to other stations during the tuning cycle.

Typically, the auto-tuner is designed to match load impedances in the range 16-150 Ω resistive (load VSWR = 3:1 max.) Insertion loss is 0.5 dB when matched to VSWR < 1.5:1 at the tuner input. The auto-tuner is not intended to match highly reactive loads, such as non-resonant antennas. A suitable external tuner can be connected to the amplifier output for this purpose.

The auto-tuner must be disengaged when using an external tuner. Cascading tuners can reflect high reactance values back into the auto-tuner and/or LPF. As a result, dangerously high RF voltages can appear across capacitors in these networks, leading to component failure.

An internal auto-tuner in a 1 kW-class amplifier requires some cooling, to remove heat generated by losses in the inductors and fixed capacitors. This is accomplished by a small fan in the auto-tuner compartment, or by the diversion of a portion of the amplifier cooling air through the tuner area. (For 1 kW delivered to the load, with 0.5 dB insertion loss, the auto-tuner T-network dissipates 125 W).

Depending on the controller design, the auto-tuner may either track frequency and load-impedance changes dynamically, or store and hold settings previously established during a tuning cycle. The controller also switches taps on the inductor, and switches in fixed capacitors as needed for the lower frequency ranges[3]. Further, the auto-tuner will provide a certain amount of additional receive preselection.

External Interfaces

In addition to the usual RF input, RF output (antenna), keying, ALC, and power connectors, a solid-state amplifier is usually fitted with a "band data" input. This enables the exciter to send band-selection information to the amplifier controller. The band-data format is proprietary and unique to each equipment manufacturer. In some designs, a reverse-keying line allows the amplifier to key the exciter, to request a carrier. The amplifier controller counts the carrier frequency to set the correct frequency range. This feature preserves automatic band switching when the amplifier and exciter are of different makes.

Many solid-state amplifiers offer dual RF input, keying, and ALC interfaces, allowing the operator to switch between two exciters. Separate ALC adjustments are provided for the two inputs. In addition, up to four selectable RF outputs may be provided. These may be programmable, to permit automatic antenna selection by frequency range or band.

The keying (PTT) line in a solid-state amplifier is low-level and designed to be driven by an open collector or a light-duty reed relay in the exciter. No auxiliary keying relay or buffer is required. Some designs support QSK with a compatible exciter, via the keying line and a transmit-inhibit line.

Depending on equipment configuration, the external interfaces (other than power and RF) may be grouped in multi-pin connectors, to facilitate interconnection with the exciter. In addition, keying and ALC lines are usually brought out to RCA jacks.

Some newer amplifiers are also fitted with an RF sampler at the LPF output. This feature provides a low-level sample of the output signal for exciters with pre-distortion linearization.

Power Supply Unit (PSU)

The PSU may be internal or external; both linear and switching types are encountered. Generally, 500 W-class amplifiers are sold with a companion 1.5 kVA linear or switch-mode PSU rated at 40 or 50 V at 25 A output, whereas a 2.5-kVA switcher rated at 48 V at 50A output is provided with a 1 kW-class amplifier. The PSU incorporates inrush-current limiting. Some 48-V PSU designs allow switching to a lower output voltage (typically 35 V) for half-power operation of the associated amplifier.

A well-designed PSU will incorporate extensive RF decoupling. The potential purchaser of a solid-state amplifier should not be concerned if it has a switching PSU. Modern switching PSUs designed to operate in an RF environment are fully EMC-qualified. In addition, it goes without saying that a switching PSU is much smaller and lighter than a linear design with a large, iron-cored mains transformer.

To ensure optimum linearity, the PSU must be well-regulated (approximately 5% output voltage drop at full load). A well-regulated collector/drain dc supply is essential to obtaining good linearity. It allows optimizing the collector-to-collector (or drain-to-drain) load resistance for good efficiency and controlled current swing, without going into saturation.

The base- or gate-bias regulator must be absolutely stable and free from RF or envelope modulation. Careful attention to the bias supply performance is necessary for the best linearity of which the power devices are capable. To reduce standing collector (or drain) dissipation in the RF power devices, bias voltage is applied only when the PTT line is in the transmit state. During standby, the devices are at zero-bias (non-conducting). RF-sensing electronic bias switching is not normally used in a solid-state amplifier.

Operation from 220 ~ 240-V ac mains is recommended, to minimize the effects of mains-voltage drop. The PSU should incorporate an adequate forced-air cooling system. A two-pole circuit breaker in the primary mains circuit is an excellent safety refinement.

A remote-control panel is a convenient operating feature offered with some high-end solid-state amplifiers.

NOTES

[1] *HF Radio Systems & Circuits*, Sabin & Schoenike, eds. Chapter 12, Noble, 1998.
[2] *Single-Sideband Principles and Circuits*, Pappenfus et al., pp. 370-371. McGraw-Hill, 1964.
[3] **www.ab4oj.com/atu/main.html**
[4] *The ARRL Handbook for Radio Amateurs* (2001), Fig. 6.87.
[5] Motorola Engineering Bulletin EB-104.

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