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SOFT STARTING

WHAT IS A 'soft start' circuit, and why should my power supply need one?

A SOFT START circuit is a way of turning on the mains supply gradually, to avoid stress on components due to a sudden voltage or current surge. In a typical transformer rectifier capacitor power supply (**Fig 1a**) at the moment of switch-on, the primary of the mains transformer looks like a very low resistance because the core is not magnetised. The larger the transformer, the lower the primary resistance, of course, and therefore the larger the switch-on surge. Mechanical movement inside the transformer is what's responsible for the loud 'thump' when you switch on, and obviously such stresses aren't doing the transformer any good - and likewise the mains switch. Beyond the transformer, the uncharged reservoir capacitor also looks like a short-circuit, and the initial current surge stresses all the components upstream of it. In a power amplifier using valves, there are also the heaters or filaments to be considered. These have a much lower resistance when cold than when up to temperature, so once again an uncontrolled switch-on causes a severe thermal and mechanical shock which will definitely lead to reduced life expectancy. The other problem is that a mains fuse or circuit breaker selected to give fast, sensitive protection in normal operation is unlikely to allow the equipment ever to start!

Because most components are rated to survive moderate switch-on surges, small power supplies can get away with a simple mains switch, and possibly a slow-blow fuse. The surge is bigger and more serious in larger power supplies. Although the peak current through any individual component is always limited by the resistance and inductance of all the other components upstream, starting with the mains wiring itself, it's better to avoid these stresses by deliberately limiting the current surge for the first few moments. That's what a soft-start circuit does.

A typical soft-start circuit places a resistor in series with the mains supply for a brief period during switch-on, a few seconds at most. Some kind of timing device then operates a relay which short-circuits the resistor until the equipment is switched off. Strictly speaking this is a 'step-start' circuit, but 'soft-start' is the more common name. **Fig 1b** shows an outline circuit. Values for the limiting resistor R1 range from about 500Ω down to about 20Ω, so you may need to experiment to see what suits your equipment. The resistance should not be so low that it provides very little surge-limiting effect at switch-on, but it definitely shouldn't be so high that the main current surge comes *after* the resistor is shorted. The power rating usually needs to be only about 50W, because the esistor is only dissipating power very briefly

If you're adapting an American design, you needn't follow their common practice of using a series resistor on each side to the transformer primary.

There are many different kinds of timing circuit, but they fall into two main groups. One measures a time period and then closes the shorting relay. The other kind senses the build-up of voltage at the 'downstream' side of the components that are being protected. **Fig 2a** shows the commonest and simplest of the timer-type circuits. D1-R2-C1 form a simple rectified mains supply for the 24V DC relay RL1, but the time constant of R2 and C1 delays the build-up of voltage across the coil of RL1. When RL1 finally closes, RL1a shorts the series resistor R1. The values given are adequate for a wide range of transmitter power supplies (regardless of output voltage). A disadvantage of this circuit is the continuous power dissipation in R2, typically 25W. **Fig 2b** shows a more sophisticated approach. This is representative of a large group of soft-start circuits that use one of the classic transistor/IC delay timers with a small independent power supply that is energised at switch-on. In this case the 555 timer starts when power is applied, and the output (pin 3) goes high after about 1 second, energising RL1 and short-circuiting R1 until all power is switched off.

Fig 2c shows a simple soft-start circuit that indirectly senses the build-up of output voltage in a transformer-capacitor-rectifier supply [1]. RL1 is a 24V DC relay that is supplied from two primary taps on the mains transformer that are nominally 20-25V apart. Bridge rectifier BR1 and series resistor R2 feed RL1 from the available AC voltage, which will build up slowly as the transformer is magnetised and the main reservoir capacitor is charged. In effect, the whole circuit acts as its own timing element. R2 is adjusted so that RL1 will pull in after a suitable time. Some experimentation will be needed, because the correct value for R2 will depend on almost all the other components acting together; about 200Ω (2W) would be a good first try.

Although some of these soft-start circuits appear delightfully simple, you do have to remember that if anything goes wrong, RL1 will never pull in, and then R1 may become very hot indeed. One way to deal with this is to choose a fairly short time delay, and protect R1 with its own slow-blow fuse FS2 that never normally has time to operate. Fig 2c shows the location for FS2, which could (and probably should) be used in all of the other circuits too. An alternative to a wire fuse would be a so-called 'resettable fuse', which is actually a Positive Temperature Coefficient (PTC) resistor. These components have a large, positive resistance change if they reach a certain temperature, and will then limit the current permanently to a safe value; they are re-set by removing the supply voltage and allowing them to cool down, and thus can be cycled indefinitely. PTC resettable fuses are in the Fuses section of the major component catalogues.

That leads us to another type of soft-start circuit, based on a Negative Temperature Coefficient (NTC) resistor all on its own (**Fig 2d**). This type of component has a high resistance when cold, falling to a low resistance when it has warmed up, and that's all you need to ensure a gradual soft start. Disadvantages are that component selection is needed because performance is load-dependant; the component won't work unless it is deliberately allowed to get hot in normal operation and is protected from draughts; and the residual resistance will affect the output voltage stability. The RS catalogue logically calls these components 'Inrush Current Suppressors' and you'll find them in the *Suppressors* section, but in the Farnell catalogue you need to look under *Resistors* for 'Thermistors, NTC'.

Last of all, let me repeat the advice to include a suitably rated mains filter at the input to all power supplies. A VDR should be connected between line and neutral to suppress mains spikes, but to minimise the risk of long-term deterioration it is best to connect this component downstream of the filter and mains switch

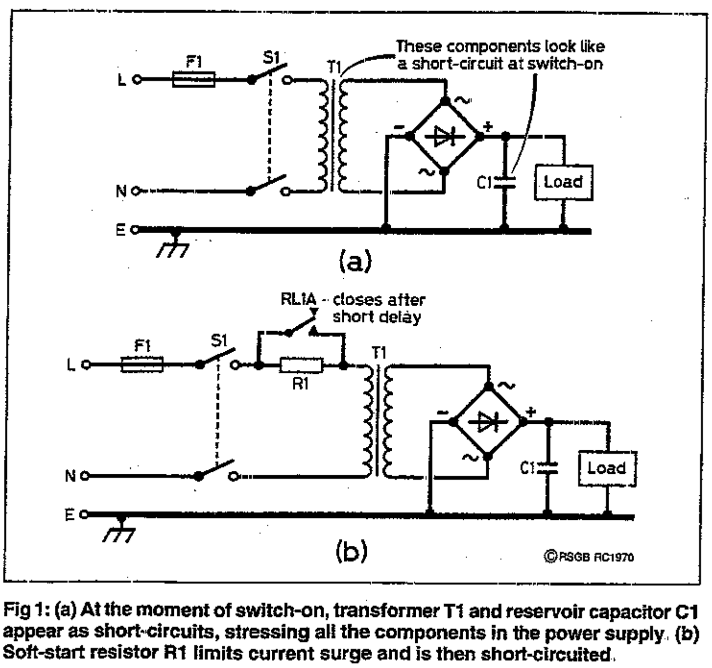

Fig 1: (a) At the moment of switch-on, transformer T1 and reservoir capacitor C1 appear as short-circuits, stressing all the components in the power supply. (b) Soft-start resistor R1 limits current surge and is then short-circuited.

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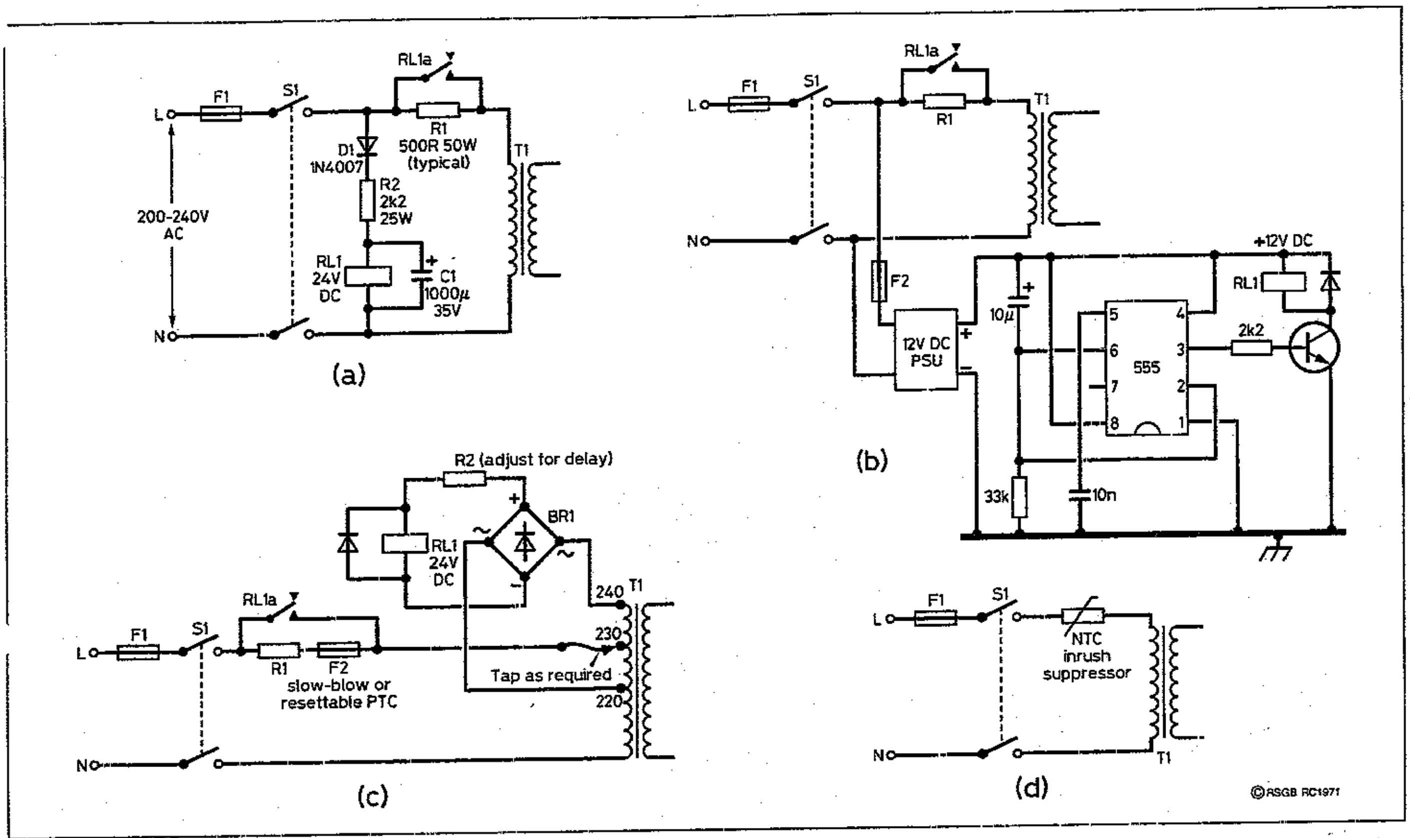

Fig 2: (a) A very common primary-side timer circuit. (b) One of many possible timer circuits using an auxiliary low-voltage supply. (c) Simple voltage-sensing circuit, but note the PTC protection for R1 which could also be used in the other circuits. (d) NTC resistor provides a very simple soft start, but with some disadvantages.

MODIFYING PC BOARDS

HOW DO I drill a PC board that already has components on, without breaking the drill bit?

IN ONE WORD, carefully. There's often a need for a few extra holes in an experimental PC board, or one that you're modifying, but the existing components on the board make the job much more difficult. For a start, hold the board firmly - not in a vice, but flat on the bench using a sheet of expanded polystyrene underneath. Press the underside of the board down into the sheet until it sits firm and level. To prevent the drill from skidding - and inevitably breaking - mark where the hole is to be with a sharp scriber. Dig a deep enough dimple to locate the point of the drill bit.

You need a drill that you can control very finely and does not put sideways strain on the bit - because it will break. A small high-speed electric drill in a bench stand is ideal, but even here you have to locate the board very accurately so that the bit goes straight into your starter mark - or else it will break. If you have to drill freehand, without the bench stand, the same electric drill is probably still the best option, but has to be used very carefully. Brace both wrists against the bench and move only your hands. Don't let your body weight come to bear on the bit, or else . . . well, you know! Also, avoid using any kind of hand drill with a side crank handle; that's a sure way to put sideways forces on the bit. When I can't be bothered to get out the drill and stand, I've had some success with a miniature Archimedean screw drill, where all the forces are along the line of the bit . . . but I've also broken lots of bits.

WIND LOADING

HOW DO I calculate the wind loading on my antenna and mast?

IN JANUARY 1995 this column showed an easy way to calculate wind loading, which simplified the calculation by treating all the antennas, rotator and mast as flat slabs. That approach maximises your estimates of the wind forces because it takes no account of streamlining effects, but it also tends to ensure that the whole installation is over-engineered. In a small installation, over-engineering doesn't cost much; but with larger antenna systems the costs of heavier-duty towers, rotators and masts escalate rapidly, and you literally cannot afford to over-engineer. Instead, you have to get the calculations right.

Computers to the rescue! A program called *YagiStress* by NI6W allows yagis and support booms to be optimised for mechanical strength and minimum weight. Tell *YagiStress* what kind of yagi you propose to build, including all the lengths and cross-sections of materials involved, and the program makes accurate estimates of the total weight and the static balance about the mast mounting point. Then it analyses the wind forces and aerodynamic balance of your proposed structure (using methods that have been checked against even more accurate computer codes), and calculates the loading on each component over a range of wind speeds. It even asks, "Would you like ice with that?" One of the main virtues of *YagiStress* is the ease with which you can change your ideas and re-analyse the effects, and there is also an interface with K6STI's antenna performance analysis programs. There is more information at http://freeyellow.com/members3/yagistress where you can also e-mail for a free demo version.

REFERENCE

[1] Variants of this circuit seem to have been re-invented several times. It has been featured in *Technical Topics* and also in *QST*.

THANKS AGAIN

THANKS AGAIN to all the readers and correspondents who make this column so interesting to write. Much of *In Practice* is based on other people's knowledge and experience, so thank you all for allowing me to pass it on. Happy holidays and best wishes for 1999. ♦

If you have new questions, or any comments to add to this month's column, I'd be very pleased to hear from you by mail or E-mail. But please remember that I can only answer questions through this column, so they need to be on topics of general interest.