



Basic Principles For Reverse Pulse Plating

Electrical resistance paths are even more important for reverse pulse plating than for DC in the same way that fine tuning is more important for a high performance racing car than for the average shopping car.

However, for reverse pulse plating there are some additional factors that need consideration. These additional factors concern pulse shape and pulse stability.

Pulse Stability

Pulse stability is dependent on the characteristics of the electrical load and variations in load impedance can cause an unstable pulse waveform.

The benefits of reverse pulse plating are achieved by the interaction of the reverse pulse with one of the organic additives in the electrolyte (brightener). Pulse instability will tend to inhibit this process and reduce the benefit.

The most common cause of problems with pulse plating is due to variations in load resistance. Even small changes in resistance, which might not trigger an appropriate fault response from the unit, may lead to a deterioration in plating performance.

From Kraft's extensive experience, the most common faults that lead to high resistance or pulse instability are:

1.1 Corroded or Dirty Cathode Saddles/Flight Bar Connections

These should always be clean and designed to give the maximum possible contact pressure. A poor contact at one end of the flight bar will obviously increase the total resistance by 100% and make the quality of that contact extremely critical. Both contact surfaces, saddle and flightbar, must be kept clean. All corrosion and arcing damage should be removed.

1.2 Anode Polarisation

Insufficient **effective** anode area will lead to anode polarisation at higher plating currents. This is usually evident from a slightly high cell voltage at the beginning of the plating cycle. This voltage will eventually begin to rise at an increasingly rapid rate, until the threshold voltage is reached when the unit will shut down.

Anode polarisation can also be caused by low or high chloride in the electrolyte.

For some new electrolytes, insufficient filming of anodes can lead to adsorption of the additives onto the anodes. The greasy, grey film has a high resistance and will reduce the effective anode area. This leads to anode polarisation at higher currents. This film can only be removed by removing the anodes and acid dipping. Unlike normal anode polarisation it cannot be removed by plating at low anode current density.

1.3 Cathode Vibration

Cathode vibration during the plating process makes the quality of the cathode saddle more critical. Excessive vibration may lead to electric arcing which will rapidly degrade the cathode contacts, increasing stress on the pulse unit and diminishing the benefits of the process.

Experience has shown that excessive vibration during electrodeposition can lead to a poor quality copper deposits with poor grain structure and mechanical properties.



Fig. 4 Multi Puls is a flexible and reliable rectifier for reverse pulse plating

Inductance

Up to now, all of the factors which are important for DC plating are equally important for reverse pulse plating. The additional factor that is of paramount importance when using pulsed current is that of inductance. Simply put, this is a measure of a conductor's resistance to the rapid change in current required by high frequency pulses. Inductance is caused by the induced magnetic field around any conductor when current flows. The inductance of a conductor is a function of the current and the length of the conductor.

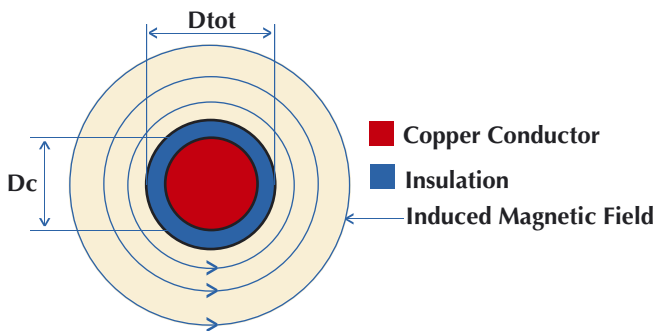


Fig. 5 Induced Magnetic Field around Conductor

There is only one way of overcoming inductance – by applying voltage according to the following formula:

$$T = \frac{L \times \Delta I}{U}$$

Where T = current rise time (microseconds)
 L = Inductance (microHenries)
 ΔI = Change in current (amps)
 U = Applied voltage

For example, if a cable installation has an inductance of 2 microHenries, and the pulse unit has a maximum available voltage of 32V, a change in current of 2500 amps will take 156 microseconds.

Once the applied voltage reaches a safe limit (about 40V), there is nothing a pulse rectifier can do to reduce current rise time. There is nothing magic or clever about this, the voltage output at the output connections is the only determining factor in deciding current rise time.

Typical pulse waveform from a Kraft Multipulse is shown below:

Output 25A with reverse current ratio 4 : 1

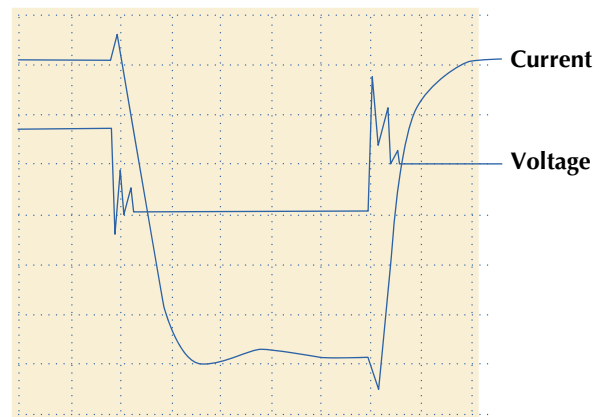
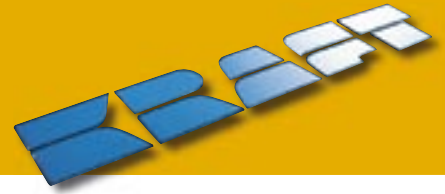


Fig. 6 Typical Reverse Pulse Waveform



Reducing Inductance

So, if inductance cannot be overcome the installation will have to be designed to minimise it.

Shorten Cables – cables and busbars should be as short as possible

Pair positive and negative cables so that the induced magnetic field from one is cancelled out by the other.

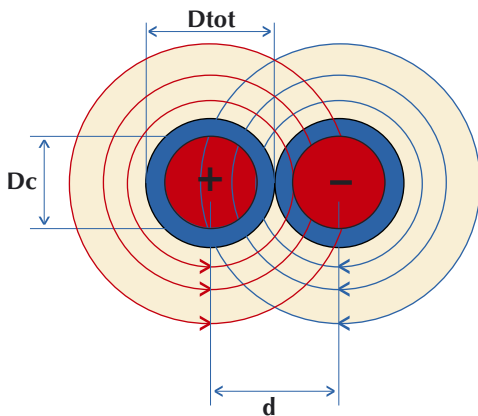


Fig. 7 Paired Cables Reduces Total Magnetic Energy

The lower d , the less the total energy in the magnetic field.

Typical inductance of the above arrangement using 70 mm^2 welding cable is $0.33 \mu\text{H}/\text{meter}$.

Use Co-axial Cable

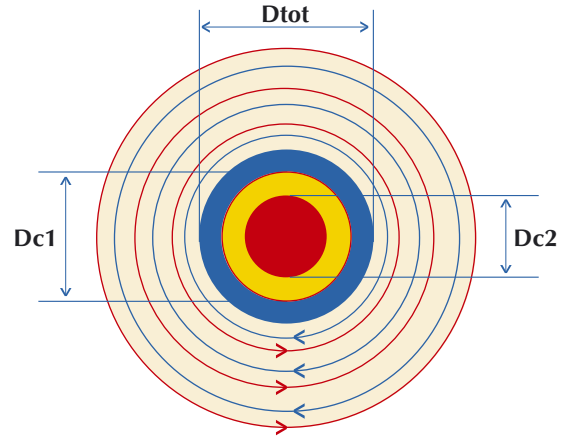


Fig. 8 Co-Axial Cable

The inductance of co-axial cable equivalent to the paired cables above is about $0.17 \mu\text{H}/\text{meter}$.

The inductance of co-axial cable is much lower than the equivalent length of paired cables but is much more expensive and is more difficult to install. The copper diameter will have to be larger than conventional cable as the temperature rating will be lower. This is immensely important as, when overheated cables cool, corrosive chemicals from the process are drawn into the body of the cable where the continuous heating will soon lead to corrosion. Replacing any kind of cable on a large plating line is difficult, replacing co-axial cable is expensive too.

Generally, Kraft experience shows that, for a correctly designed pulse unit, the use of co-axial cable is unnecessary.

PULSE SHAPE

A typical reverse pulse waveform is shown in Figure 6 above. However, this shows a pulse shape taken at the output of a pulse rectifier and, where it really matters at the cathode surface, the pulse shape may be very different. This is because the rapidly changing part of the pulse, at the start and end of the reverse pulse, is affected by the impedance of the circuit.

A typical production plating cell will comprise many parallel circuits and, inevitably, each of these circuits will have a different impedance. This is demonstrated by using a computer model to simulate a simplified circuit to represent a cell.

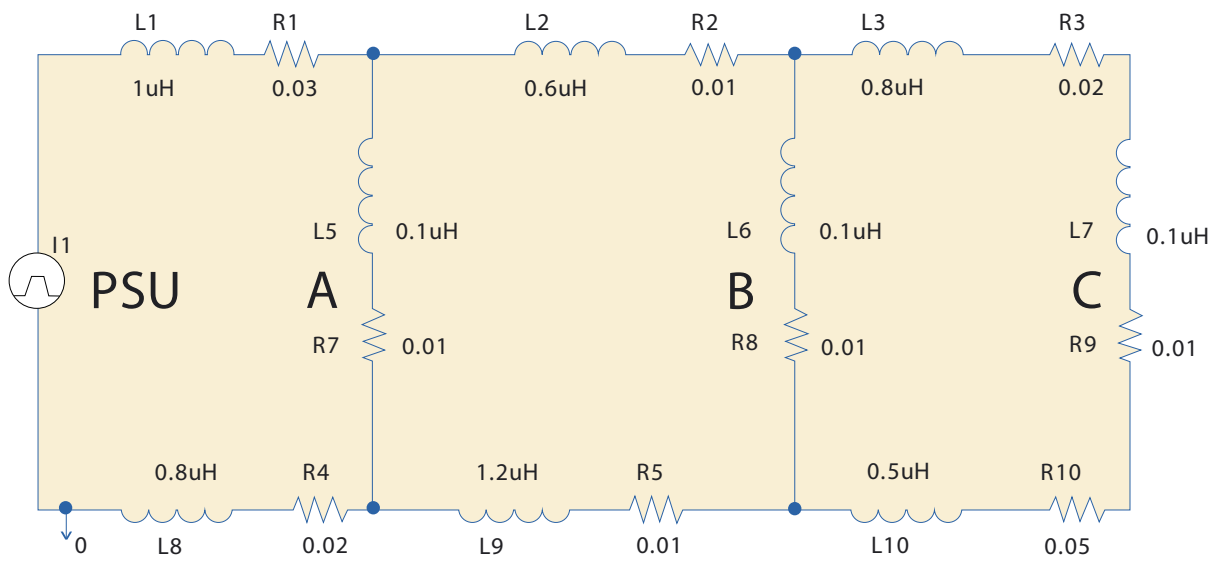


Fig. 10 Simple Circuit Model for Electroplating Cell

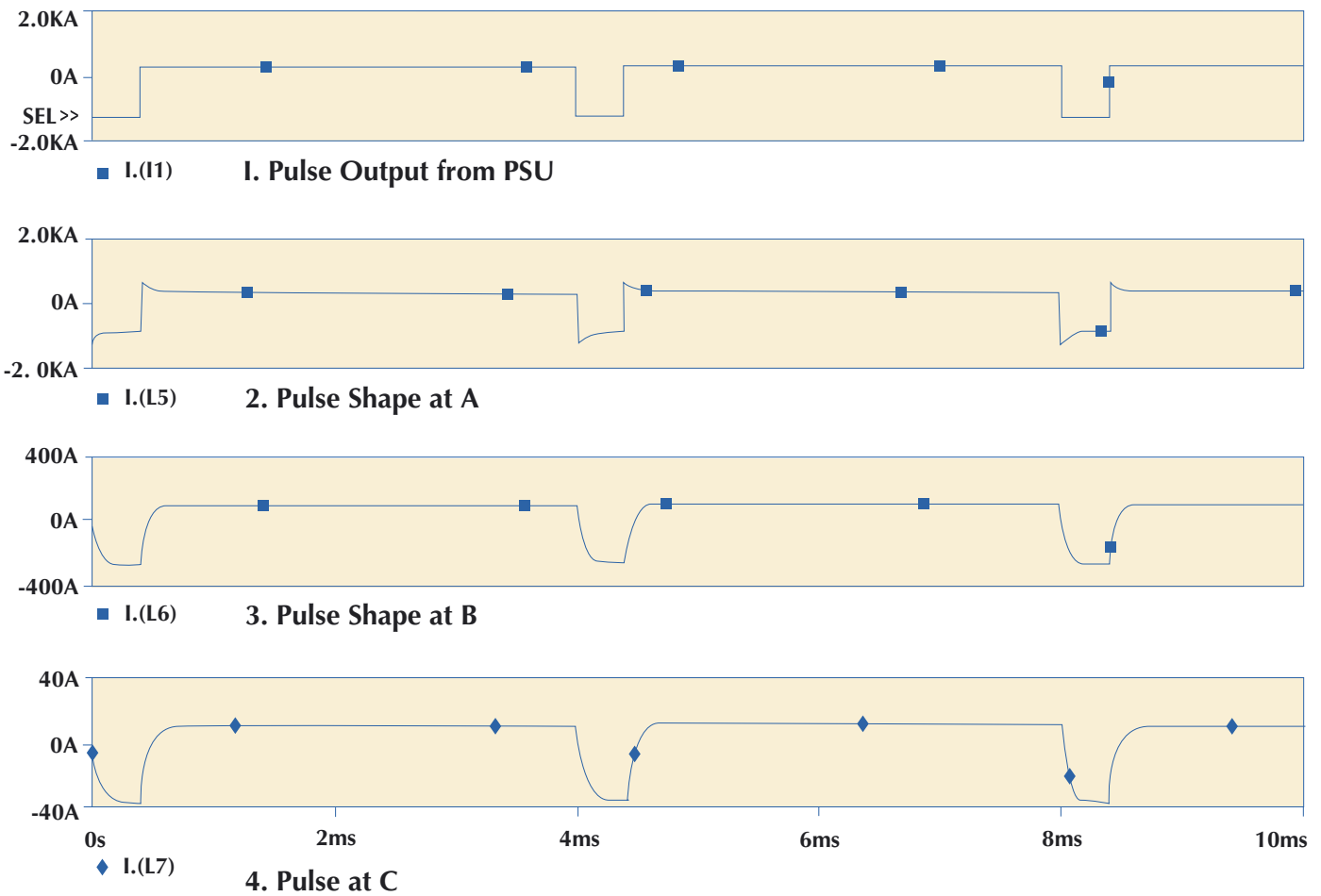
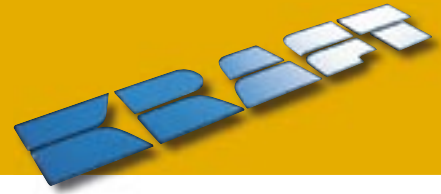


Fig. 11 Computed Pulse Waveform at Various Positions in Circuit

With an input reverse pulse which is perfectly square it can be seen that the actual pulse waveforms in the middle are quite different from those at the ends. The explanation for this is that the rapidly changing edges of the pulse will always tend to follow the lowest impedance which, in our model, is at the end of the cathode rail. This leads to a tendency to overshoot at the ends, and to undershoot in the middle.

Fortunately, the performance of the reverse pulse process is not too critically dependent on this aspect of the reverse pulse.

Chemistry of Copper Plating With Reverse Pulsed Current

Figure 4 showed how the cell resistance equals the sum of the electrolyte resistance and the transfer charge resistance. As acid copper plating is normally 100%

efficient, the only way we can improve the distribution of metal over a complex cathode surface is by changing the transfer charge resistance over the surface to compensate for the primary current distribution.

All pulse compatible copper additive systems use two organic additives which were originally used in DC systems to give the correct mechanical properties of the copper deposit. These additives are generally referred to as:

1. Brightener
2. Wetter, carrier, leveller or grain refiner

During electrodeposition, both of these additives are adsorbed onto the copper surface. The brightener has the effect of reducing the transfer resistance, the carrier has the opposite effect. Together, they actually reduce the resistance which, for conventional DC plating, will make the metal distribution worse than if they were not there.

During the reverse pulse, the brightener is de-sorbed from the surface in the high CD area so that, in the next forward pulse, the transfer resistance is increased on the surface of the board. The current is therefore reduced on the surface and increased in the low CD area, inside the holes.

Eventually the brightener is re-adsorbed onto the surface and it is then time for the next reverse pulse. Obviously, if the reverse current density is too high, brightener will be de-sorbed inside the hole and the improvement in throwing power will be lost.

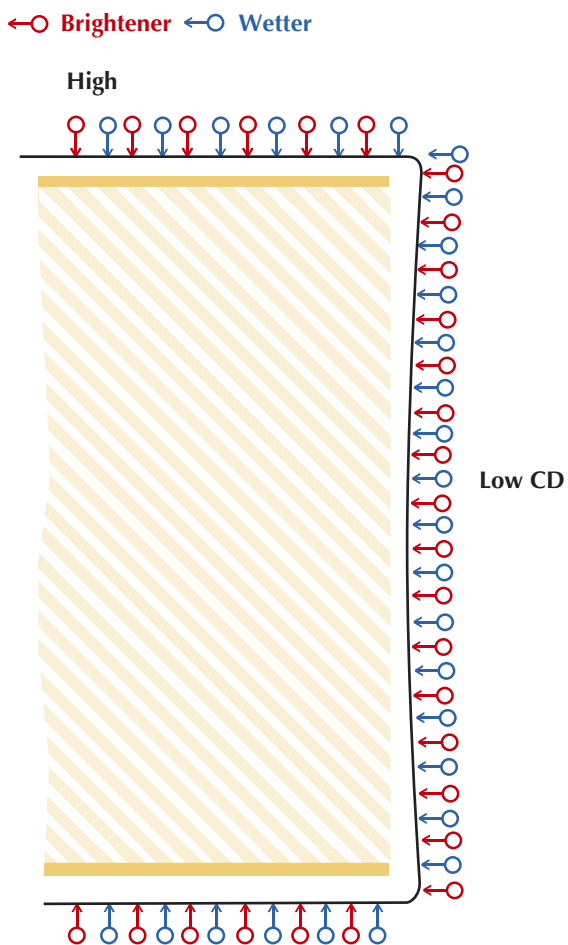


Fig. 12 PCB Hole (one side only) showing additive adsorption for DC

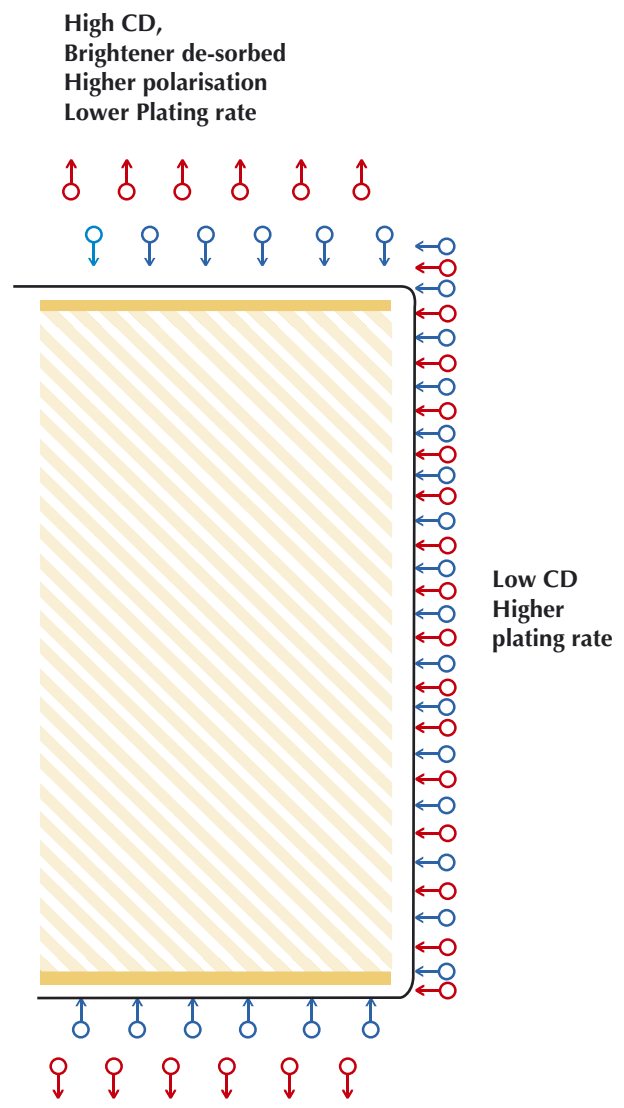


Fig. 13 Brightener Desorption during Reverse Pulse

