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Subject: [*] Crystal Speedup History 2.3

Mac Crystal Oscillator Speedup History 2.3

April 1994

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A little background:

All computers operate at a certain frequency with which operations are performed. Within a certain class of computers, for example Mac's with a 68030 processor, the higher the frequency, the higher frequency of operations processed, and the faster the computer provided there is no other speed effecting hardware like a cache or slow data path. The designer of the computer, Apple in this case, will use components that are rated at the same frequency or faster than the final computer will be. The 68030's are made by Motorola. All 68030's are generally alike in what they do, but they are not alike in how fast they can do it. Motorola sells several 68030 processors rated at 16, 20, 25, 33, 40 and 50MHz for Mac's, accelerators and such. A large frequency difference will require a different mask during production of the processor, but small changes may not. Motorola only needs to guarantee that the chip they mark as 20MHz will function properly at 20MHz under a variety of conditions. Some chip vendors will test parts at different frequencies and sort the chips accordingly while others may just label the them at will and sell the chips at the different price as long as they are within spec. So it is possible that the 20 and 25's actually come from the same batch, are separated on demand, and tested to make sure they will withstand that frequency. Because of

this, it is possible that a 20MHz processor will function fine at a higher frequency, say 25MHz. Running it faster will however generate more heat.

Many of the components in the computer need to be synchronized, so a frequency is generated by a crystal oscillator to synchronize them. Other parts like NuBus cards and video do not have to be the same frequency, so they may have separate crystal oscillators. A typical computer may have several crystal oscillators to clock different groups of components on the motherboard. Provided the components that are clocked by a particular crystal oscillator are capable of a speed increase, that crystal oscillator may be replaced with one of a higher frequency. How much a specific Mac can be sped up by this method depends on how the motherboard was designed, the components used, and what things the crystal oscillator that controls the processor also controls. With some of the newer Mac's, there are a few MHz differences in the top speeds reported for the same model, so part of this is luck of the draw.

This crystal oscillator swapping has been done for years, and some early computers even had jumpers that made it really easy to disable one oscillator and enable another higher frequency one. The first Mac's to be modified were the IIsi's. A stock IIsi's runs at 20MHz, and IICI's at 25MHz, and since the architecture of these machines was so similar it seemed reasonable to run a IIsi at IICI speeds. Another important factor was that earlier Mac's had just one crystal oscillator that controlled everything, and if you replaced it you would mess things up. The IIsi was different as some noted through its frequency deviation from its 8 and 16MHz precursors where the main frequency was halved and quartered to run the CPU, serial ports, video... The IIsi was different, it had 4 crystal oscillators, only one of which controlled the processor speed.

The Crystal Oscillator:

The type of crystal oscillator in the early Mac's is a full size, 14 pin package, TTL type crystal oscillator. It is a rectangular metal can, with approximate dimensions of 2.0 x 1.3cm and typically about 0.3-0.6cm high. All crystal oscillators have 4 pins. Some are numbered 1,2,3,4 and others 1,7,8,14. Pin 1 is always the pin next to the pointed edge (the others are rounded), with the dot, or next to the indentation on the newer CMOS, or surface mount crystal oscillators. With the pins facing down, put the dot, or indentation to your left, and the pin on the left, closest to you is pin 1. Going counter clockwise, pin 2 (or 7, depending on what numbering scheme) is to the right, Pin 3(8) right side and further away, and 4(14) left side, and further away. Pin 1 on all the newer Mac's with surface mount crystal oscillators, and some of the older ones is an output enable/disable pin (OE). On some of the crystal oscillators you purchase Pin 1 will be OE, yet on many it will not be used (no contact (NC)). It is not important which you get as you will not be using the output enable feature. Pin 2(7) is a ground. Pin 3(8) is the output. Pin 4(14) is the supply voltage, +5 VDC. I've checked a few of the older type Mac's, and the oscillator on Mac Plus's is not OE, while the ones on the IIsi's and Quadra 700's are OE. I'm not sure why Apple uses these type of oscillators instead of the ones where pin 1 is not used. I guess it is possible that something on the circuit board can ground pin 1 and stop or restart the computer. If anyone knows, please let me know. Printed on the crystal oscillator will be its manufacturer, part numbers, and frequency. On these early Mac's, the processor runs at half the speed of the oscillator, so a 20MHz Mac IIsi has a 40MHz crystal oscillator.

There are several different modification techniques. They will all give you the same final max speed. Some are just easier or more elegant than others. As with all these modifications, even though there may be no visible sign that you modified your Mac, you have voided the warranty on the Mac. As Apple states:

"This warranty does not apply if the product has been damaged by accident, abuse, misuse, or misapplication; if the product has been modified without the written permission of Apple; or if any Apple serial number has been removed or defaced."

This is what I seem to be finding. These numbers vary from Mac to Mac, so these are just averages. Some machines will go faster than this. These are the oscillators that Output Enablers ships in their kits.

Modifications:

Machine	Mod-1	Mod-2	Mod-3	Oscillator/speed	Final Oscillator/speed
IIsi	yes	yes	no	40/20	55/27.5MHz
C610	yes	no	yes	10/20	14-14.31818/28.6MHz
C650	yes	no	yes	12.5/25	14.31818-14.75/29.5MHz
C650-mod	yes	no	yes	12.5/25	20/40MHz
C660av	yes	no	yes	12.5/25	16-17.496/35MHz
Q610	yes	no	yes	12.5/25	15-15.288/30.6MHz
Q650	yes	no	yes	16.6667/33.3	21-22/44MHz
Q660av	yes	no	yes	12.5/25	16-17.496/35MHz
Q700	yes	yes	no	50/25	70/35MHz
Q800	yes	no	yes	16.6667/33.3	20-21/42MHz
Q840av	yes	no	yes	20/40	23.247-24/48MHz
Q900	yes	yes	no	50/25	70/35MHz
Q950	yes	yes	no	66/33	?75-80/?40MHz
PM6100	yes	no	yes	30/60	40/80MHz
PM7100	yes	no	yes	33/66	?45/?90MHz
PM8100	yes	no	yes	40/80	?50/?100MHz

Mod-1

The basic idea of Modification #1 is removing the onboard oscillator, and replacing it with a faster one. This is the mod most people use on the IIsi, Q700, Q900, & Q950.

The basic procedure used is that you have to unsolder the TTL crystal oscillator from the motherboard on the Mac, and put in a new one. Instead of putting one straight onto the board, it is nice to use a socket so you can test your individual Mac, and see what the cutoff frequency is, and you can always put the original oscillator back in the socket.

First find the crystal oscillator by referring to the previous table and description of physical characteristics. Be careful when you remove the oscillator. Most people just use a normal soldering iron, and are fine; a grounded (three prong soldering iron) would be a bit safer. They just use copper wick to soak up the solder from all four pins, and pop out the proper oscillator. Because the boards are multilayer, be careful not to damage anything; be gentle. There was

recently one report of a guy who damaged his IIsi board doing this. But that was the only incident I had ever heard of, and lots and lots of people have done this. I use a "desoldering iron". They melt the solder, and have a pump to suck out the solder while you swirl the pin from the oscillator around to get all the solder out. After you have done all 4, if you have done a good job, the oscillator just pops out. If you have access to one of these desoldering irons, I highly suggest you use it as it does a cleaner job, and there is less risk of burning (discoloring) the board. Next, take a 14 pin IC socket, remove all the pins but 1,7,8, and 14, and solder it into the board (see Modification #3 for a Digi-key part number). Make sure you put it in so pin 1 will go into pin 1, 2-2, 3-3, 4-4. And the notch in the socket should face the same way the dot on the old oscillator was facing. Now just put in a faster oscillator.

I have done this to a few IIsi, and the highest frequency we could get to work without problems was 27.5MHz. Thus a speed increase from 20 to 27.5MHz. The actual crystal is 55MHz (double the frequency). TTL 55MHz crystal oscillators do exist, but they are rare. The thing most people seem to do is get a CMOS oscillator, and they work just fine. Digi-Key sells a 55MHz CMOS crystal oscillator in a 14 pin package, part# SE1509. At 58.9 and above, there are problems with the floppy drive; you cannot boot the Mac from a floppy, but other than that it is fine until just over 30MHz. I recently had a IIsi at 28.3MHz and it was fine. Be warned that some cards may not work after this modification. Most will work at 25MHz, but will not at 27.5MHz, so just stick with 25MHz if that is the case.

The IIsi does not come with a heatsink, so to reduce the heat in the processor, get a small heat sink to attach to the 68030 to cool it down; any heat sink will do; the more surface area the faster heat will be dissipated. Be careful when you put on the heat sink. Typically you'll use some heat transfer grease, but the heat sink can slide off if the Mac is moved, and the heat sink might short something out. The best thing seems to be to get a heat sink with a hole in the middle, or drill one yourself, use the heat transfer grease, but also put a small drop of super glue through the hole in the heat sink onto the chip or put a drop on the side, and this should hold it in place. Fry's sells nice heat sink/fan combo's. They run \$10 and up, and I think they are more than you need, but it should keep the processor cooler. I believe they come with a Y cable to tap into your hard drive power cable to power the fan. A more complete FAQ on this modification for a IIsi is available via anonymous ftp from [sumex.stanford.edu](ftp://sumex.stanford.edu/info-mac/info/hdwr/iisi-25mhz-upgrade-faq.txt) in `info-mac/info/hdwr (iisi-25mhz-upgrade-faq.txt)`.

For the Quadra 700 and 900, you can get 70MHz TTL crystals from Fry's. The 70MHz may not work, and you may have to back down to 66.6666MHz, the next most common frequency, Digi-Key part# CTX137. The Q700, Q900, and Q950 come with a heatsink installed. A more complete file on this modification for a Quadra 700 is also available via anonymous ftp from [sumex.stanford.edu](ftp://sumex.stanford.edu/info-mac/info/hdwr/quadra-700-clock-mod-145.txt) in `info-mac/info/hdwr (quadra-700-clock-mod-145.txt)`.

It has been reported for, but I have not yet done a Q950, but the general idea is the same. If anyone has any more info on doing a Q950, please e-mail me and I'll add it.

The basic idea of Modification #2 is to disable the onboard oscillator with a jumper and feed in a new signal on the back of the board. There are very few who have performed this mod, but I feel it is more elegant and safer since you don't have to remove the onboard oscillator. This newer, and less evasive method has been performed on IIxi's & Q700's by myself, and should work fine on the Q900 & Q950.

The most difficult and risky part of "Mod-1" above is the removal of the oscillator, and this is an alternative procedure that gets around that since the crystal oscillators Apple uses have pin 1 as OE. On a crystal oscillator with pin 1 as OE, if you ground pin 1, you disable the output from pin 3(8), and you can feed a new signal into pin 3(8) without removing the original crystal oscillator. Several months ago I performed this modification on a Quadra 700 by tacking (soldering) a jumper on the back of the motherboard between pins 1 and 2(7) of the 50MHz oscillator, and ran wires about 8 inches long each from pins 2(7), 3(8), and 4(14) to a 14 pin socket attached to the inside of the Q700 with pins in positions 7, 8, and 14. Into this we placed a 70MHz crystal oscillator and the Mac ran fine at 35MHz and is still doing fine. This modification is nice in that it is a bit less risky as far as damage to the motherboard, but you have to be careful to use thin wires in order to make clean solder joints. With this modification you could remove the wires at a later date to return to the original configuration more cleanly. I cannot say for sure if this will work on a Q900 or Q950 until I put one of those crystals on a scope, or actually try the modification, but am pretty sure it will. If anyone has removed a crystal from a Q900 or Q950 and still has it, I'd be glad to check it out and send it back to you.

Mod-3

The basic idea of modification #3 is building a clip that disables the onboard oscillator, and feeds in a new, faster signal. The beauty of this modification over the others is that you do not have to do any soldering on the motherboard itself, just on the part you clip onto the surface mount crystal oscillator in your Mac. This is the modification most people use on the C610, C650, C660av, Q610, Q650, Q660av, Q800, Q840av, PM6100, PM7100, PM8100.

The really neat thing about this came into play in February 1992 when Apple released the Centris 610, 650, and Quadra 800. In these machines and since, Apple has been using surface mount crystal oscillators. Now that Apple was using surface mount crystal oscillators, there was plenty of accessible area on the metal tabs of the oscillator. In June '93 Guy Kuo reported the first crystal swap of sorts on a Centris 610 to the net. He soldered pins 3, 5, 10, and 12 of a 14 pin socket directly onto the surface mount crystal oscillator. Because the pins on a TTL type crystal oscillator are at positions 1, 7, 8, and 14, he made jumpers between pins 5-7, 8-10, and 12-14. He disabled the on-board surface mount crystal oscillator with a jumper between 3-5. Then put the new crystal in the socket. This file is also available on SUMEX in info-mac/info/hdwr (centris-610-clock-mod-11).

I was a little hesitant about soldering onto my new Quadra 800, so wrote to him a few days later about using a surface mount test clip, and asked his thoughts. He suspected I could not find a reasonable test clip, but otherwise believed it would work. A few days later the 3M surface mount test clip arrived, and the test clip worked perfectly. I was running my Quadra 800 at 40MHz, with no problems,

and best of all the modification was all contained in a simple little clip that could be removed without trace at will. And thus the removable test clip approach was born. My Q800 even worked at 48MHz as long as I did not access the serial ports. A few days later I got several crystals, and found the highest frequency on my Quadra 800 to be 42.0MHz. Since then I've tried it at 42.106MHz, and the serial ports did not work, so the cutoff for my Q800 was at 42.0MHz. If you never use your serial ports, 48MHz worked fine for me, while at 50MHz my Mac was not happy and would not boot.

So if you are still interested, you will need a surface mount test clip; 3M and Pomona make them, and I prefer the 3M ones. Make sure you get a surface mount test clip. The I.C. test clips also work, but I prefer the surface mount SOIC (small outline integrated circuit) ones. A 10, 12, 14, 16, or 18 pin clip will be fine. I'd say go with a 14 or 16 narrow or wide.

14 pin, part# 923650-14-ND \$6.58
16 pin, part# 923650-16-ND \$6.96

These are the part numbers for the ones with alloy leads; I used to recommend the gold coated ones, but the resistance/corrosion effect is minimal.

You will also need a 14 pin IC socket, there are plenty of types. The machined pin ones are nice because you can pop out the pins that are not needed to get them out of the way since you only need three pins in the socket.

14 pin IC socket w/tin pins, part# ED3114 \$0.57

You will also need an oscillator (more on this later), a little wire, soldering iron, solder, and possibly heat sink depending on the machine. For a C610, C660av, Q610, and Q660av you should add a heat sink, HS160-ND is the 0.600 inch one, and is plenty (\$3.98).

The others already have heat sinks, and do not get too hot. I had an extra fan with my Q800, but removed it, and it has been fine. The heat sinks come with the clips needed to attach them to the chip. These are a bit of a pain, you just have to work at it for a while. There may be several ways to do it, but I just slide the clips on from the side. Sometimes they fall off half way there, but eventually it works. Some people have been using the heat sink/fan combo's. I have not, but they seem to work fine as well. The new Q610 and Q660av computers are based on a new mask of the 68040 that comes at 25MHz without a heatsink (There is an "H" after the '040 and before the "RC"). This is the same mask as the C660av and Q840av uses. If you do the modification on them it would be best to add a heat sink.

How to put it all together:

Stand the clip so it's jaws are facing down, and the rows of pins go >From left to right, and call the closer row A and the further row B. Number the pins from left to right 1 through 7 (for the 14 pin clip). Next place the IC socket with the pins down, and the notch to the left, and number the pins as 1, 2, 3, 4, 5, 6, 7 in the row closest to you, going left to right. The other row is numbered 8, 9, 10, 11, 12, 13, 14 as you go right to left (back towards the notch). Now starting with the test clip, leave pins in positions A2, A6, B2, and B6. Next solder a little jumper wire between pins A2 and A6.

Now get the 14 pin IC socket, and remove all the pins but 7, 8, and 14. Solder a jumper wire from pin 7 on the IC socket to the jumpered pins on the clip, either A2 or A6. Also solder a jumper wire from pin 8 to pin B6, and pin 14 to pin B2. If you get the narrow clip, you may want to replace the spring with one with less tension; they are like \$0.30 at hardware stores, and I cut them into two springs. This way you don't have to push so hard, and it is easier to position on the motherboard. Now put the crystal in the socket with pin 1 in 1, 2 in 2, 3 in 3 and 4 in 4.

There are several surface mount oscillators used on the motherboards. The proper surface mount crystal oscillator on the mother board will have a frequency on it half that of your computer and can be determined from the above list.

That is it, now you just clamp it onto the surface mount crystal oscillator with the notch on the socket facing the same way as the surface mount crystal oscillator. And watch to make sure the little pins clamp onto the surface mount chip. You may want to use a flashlight for this. These clips hang on very, very well, I've never had mine move in the last 9 months, nor any of the other ones I've done.

Centris 610 Ethernet Problems:

Those Centris 610's that have ethernet capability share the 10MHz oscillator with the CPU. If you replace that oscillator with a different one, your ethernet will no longer work. In January, Eckart Hasselbrink (Hasselbrink@fhi-berlin.mpg.de) posted a fairly simple hardware modification to fix this to comp.sys.mac.hardware. So if you plan to use you ethernet on your Centris 650 and speed it up, you will need to perform Eckart's modification first.

PowerMac's:

I have only done PM6100's, and it works fine at 80MHz. At 86MHz it overheats quite rapidly. With a cool hairdryer cooling the heatsink on the 601, it worked fine, but was a bit noisy :-). See the table to see which oscillator you will need to clip onto. This mod should work just fine on the 7100 and 8100 computers as well. On the 8100 the power supply may be in the way of the clip. If anyone in the Bay Area has a PM7100 or PM8100 and wants to try it, drop me a line and we can give it a spin. Or if anyone tries it, please let me know how it goes so I can add it to this file and pass it on to others who ask. The guesses on the chart about what oscillator to use for the PM7100 and PM8100 are just that, guesses.

On most of these newer machines, the problem is with the serial ports, but the speed of the memory is also important, so if you plan to boost your Mac very far, you may need faster SIMM's.

To test out the modification, the best thing to do is just use it a while. You can run Speedometer 3.23 (available at SUMEX in info-mac/cfg) to see the changes. I use Snooper with the serial port loopback plugs to check the serial ports to find their limits; Snooper also tells you what frequency you are running at in round numbers. Snooper was made by Maxa, and I am told Snooper is currently owned by Central Point Software. The current version of MacCheck is 1.0.5

(available on bric-a-brac.apple.com), and it now properly reports the computer frequency.

If your Mac does not give the standard chime at startup it means your clip is only half on. It is disabling the surface mount oscillator, but not replacing it. Just remove the clip, reposition, and try again.

Special C650 Mod:

Using the above clips, the max frequency for a Centris 650 is about 30MHz before you encounter serial port problems. Marlin Prowell (mbp@janus.com) following up on a hunch by James McPhail (jmacphai@cue.bc.ca) looked into the differences between the C650 and Q800 motherboards in hopes that a simple modification might enable the serial ports to function properly at 33MHz (Q800 normal frequency) or higher. On the bottom of the motherboard, under the IOSB chip, Marlin found two differences. R151 is installed on the C650's, and is missing on the Q800's. R152 is missing on the C650's, and is installed on the Q800. R151 is a 300 ohms resistor and R152 is a 1.2k ohm resistor. Looking at the bottom of the board, with the back away from you, R151 is 3 3/4" from the right, and 3" down. The tabs for R152 are 4" from the right, and 3" down. R151 is black, and says 301 on it.

Marlin felt that R151 was glued to the board, and just using solder braid he was unable to remove the resistor for fear that prying it off may damage the traces that run under it. Heating the resistor with a soldering iron Marlin was eventually able to soften the glue and remove the resistor. Or you can use James McPhail's two soldering iron Western technique with a soldering iron in each hand to heat each side simultaneously and flip the resistor off the board. Now just add the R152. Marlin suggests holding the surface mount resistor in place with a small screwdriver while soldering it to the exposed pads on the board.

Marlin has since used both the serial and modem ports error free while running his C650 at 40MHz, and MacCheck reports no problems. He has also checked to make sure the ethernet works, and it does. Since Marlin's initial modification, it has been confirmed by at least three people. On some of these Mac's the CPU overheats after a while, so Marlin suggests you add a fan to dissipate the heat faster >From the heatsink. You can also just run a bit slower, say 38MHz. You can purchase these 1.2k resistors from Digi-Key, but the minimum order is 200 of them. If you e-mail your address to Output Enablers at oe@well.sf.ca.us, they will send you a free resistor left over from Marlin's extra 199.

****This modification makes your Mac think it has become a Quadra 650, and the Quadra 650 did not exist when most of you purchased your Centris 650. The System Enabler 040 that came with your Centris 650, version 1.0, will not work after this modification, and your Mac will not start up unless you have already updated the System Enabler 040 to version 1.1, the current version. The System Enabler 040 version 1.1 is available from your local Apple Dealer, or you can ftp it from bric-a-brac.apple.com. Marlin suggests you also put the new enabler on all your recovery utility disks as well so you will be prepared next time something goes wrong.****

Recently a few companies have been started that replace the crystal oscillator in powerbooks to speed them up, and add a 68882. I have some ideas on how to do this, and the precautions to make. Has

anyone done it themselves? I have some info from Virgil Mehalek (vm@christa.unh.edu) who noted the differences between the 140 and 170. I'm not going to add that info until it has been attempted, but if anyone is interested in a copy of that info I can forward it to you. One important addition thanks to Virgil, worth noting now is that Active Electronics (800) 228-4836 sells the 33MHz MC68882-FN33A for \$76.95 plus S&H.

Address' for some other parts suppliers:

Fry's Electronics
340 Portage Ave
Palo Alto, CA
(415) 496-6000

Digi-Key
(800) 344-4539

Output Enablers
1678 Shattuck Ave. Suite # 247
Berkeley, CA 94709
oe@well.sf.ca.us

There are currently two companies that sell already made clip-on kits for the Mac's with surface mount crystal oscillators.

KS Labs
6326 E. Livingston Ave, Suite 131
Reynoldsburg, OH 43068
\$165/kit

Output Enablers
1678 Shattuck Ave. Suite # 247
Berkeley, CA 94709
oe@well.sf.ca.us
\$50/kit

If you have gotten any of these new machines to work, please let me know. Or if you have any questions or comments that should be added to this, feel free to e-mail me as well.

Marc Schrier
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