The Self-Tuning Piano will soon be a Commercial Reality By Karl Ellison

In winter, your music room might be a chilly 60 degrees-F at 30% humidity. Or it's summer, 90 degrees-F and 70% humidity. In either case, you push a button while holding down the sustain pedal of your piano, and the piano is brought into tune for you in about 40 seconds ...

The search for a piano that keeps it's tune will soon be over for consumers, as special mechanisms have been created and patented that will initially be incorporated into new QRS Story&Clark - initially, high-end - pianos. Don Gilmore, A Project Engineer in Kansas City, MO has applied simple high-school level physics to the piano tuning field.

Many piano tuners use devices where a microphone listens to a piano's note being played and in some form displays its difference from the ideal pitch. Vacuum tube systems would sometimes drift out of their calibration such that tuning the same note 30 minutes later could yield a slightly different result. Add to this the fact that a microphone will pick up ambient noises and harmonics that can sometimes make readings ambiguous, and you have a less than perfect manual system for tuning precision of good repeatability.

Enter computer technology. With electronics that are available off the shelf, Don designed and assembled a box that would convert a note's fundamental waveform to a square wave, and by triggering a high-speed counter to time the duration of the wave - be able to determine the length of a note's cycle. The reciprocal of this number is the note's frequency. But with microphones introducing sounds other than the played note it can be difficult for the instrument to measure the correct pitch.

Electric guitars have been using magnetic pick-up coils that generate small electrical signals when a wire in close proximity is plucked - and then separately amplified, so why couldn't they be held close to and used to pick up the vibrations of a piano wire? The results would be superior as the unit would now only 'see' the note being played.

Proper placement of the pick-up coil would also be important. The half-point of the piano wire contains mostly the note's fundamental wave, whereas near the end of the wire the fundamental plus harmonics are found - near the pin block where pick-up coils would most naturally be mounted. To be able to process only the fundamental frequency, a digital low-pass filter (1) is used. This filter chip (again, commercially available) is controlled by the device's microcontroller (2) to select the filter's cut-off frequency. Depending on which note the device wishes to analyze it tells the filter chip which frequency above which it shouldn't listen to - shouldn't "pass through" - to the frequency counter device.

Computers are good at only two things: doing fast comparisons, and storing information. With the computing power of the unit's microcontroller this inherent power could be put to work to derivate not only what the frequency of a string was vibrating at, but how much it deviated from it's ideal frequency. If the computer had a table of 'ideal' frequency values for each of the approximately 250 wires in the piano the microcontroller could tell you how much the real vibration deviated from the desired value in the table. So using the programmable filter the microcontroller commands a pulse to be sent to each piano wire excited directly though the magnetic pick-ups hovering over each wire, and reads each note by ramping the programmable filter through the entire piano's fidelity. It counts how many computer clock-ticks that happen during one cycle (Hz) of each note and compares it to it's entry

in an EEPROM (3) to tell if it's sharp or flat, and by how much. The system is accurate to be within one "cent" (1/100th of a musical half-step).

The table of ideal values isn't constant for all pianos. Each instrument is slightly different in that "canned" frequency table values won't give pleasing results. Additionally, you must also account for tuning styles that are different from the modern Equal Temperament tuning, octave stretching and the like. So the table of ideal values are tailor-made for each piano, by hand-tuning it at the factory as usual. Then the tuning is read-in and converted/saved to table values so they are unique for that piano.

Now we have what amounts to a portable tuning aid device that can magnetically excite a piano's string, read its fundamental vibrating frequency and compare it to the ideal table value to give you a difference reading on it's LCD display, and send the differential reading to a separate device to actually do something about it - like adjust the tuning of the piano. This could be sent to an actual tuning device through it's built-in infra-red LED transmitter using the common RS-232 computer protocol. This is the very device that has been awarded a US patent # 6,479,738, and will be called the PocketTune.

But what about the actual tuning device itself - the unit that takes the differential readings and does something physical to the piano?

In his earlier thought process, Don imagined a tuning device that would read the differential value sent by the PocketTune and automatically adjust the tuning pins of the piano until the difference between the wire's actual to ideal frequency were zero. The logistics of doing this proved difficult, and the reliability of this method was doubtful. What kind of device would turn the tuning pins of a piano accurately?

Then it struck Don that when metal objects are heated - when piano wires were heated, they'd expand - making the note go flatter, and if they were then cooled the note would go relatively sharper. Since piano wires are not perfect conductors they will heat up when an electrical current is passed through it. In theory, EACH note of the piano can be tuned by passing an appropriately controlled electrical current through it to - in essence, tune it.

Don now has a working prototype operational and with a patent pending (as of this writing in Feb '03) for the portion of this system that will do the actual tuning by heating each piano wire until it's frequency is equal to the table-derived ideal frequency. The device's sole function is to manage the temperature of each string in the piano. It sets the baseline temperature of each string to 95 degrees-F. The temperature the strings are heated when initially tuned at the factory, and the string's frequency values are stored in it's EEPROM table for ideal comparisons. It reads the output from the same kind of functional electronics incorporated in the PocketTune unit (though they'll be integrated into the Auto Tune system) to determine if the temperature is to be raised up to make it go more flat, or cooled down to make it go more sharp.

At the factory the piano's auto tune device will be turned on and the strings are quickly brought up to 95 degrees. A human does an aural tuning of the piano in the usual way, a tone generator and a piano hammer turning the tuning pegs. The system is then told to 'capture' the tuning into it's EEPROM table. When the power is disconnected after the tuning (and also after the user is finished using the piano for a period) the strings will cool to room-temperature, causing them to raise a third of a semitone sharp.

To play the piano, the system is turned on, and immediately the strings are brought up to the nominal working temperature. The user will then press down on the sustain pedal and press the "TUNE" button. The system will electrically 'sing' the notes through the magnetic pick-up coils, then read the strings through the magnetic pick-up coils as described earlier, calculate their tuning error, and raise or lower individual string temperatures as needed - all in about 30-40 seconds. The piano is then ready to play.

Now all the pieces are in place for a complete system. Something to read the string's vibrations, detect how much it's out of tune, and then a separate until that controls current to heat or cool the wire until it's pitch is correct.

Enclosed in this article are the 9-pages of the US Patent for the PocketTune device. The patent for the actual piano tuner - the wire-heating management hardware - are pending patent approval, and as of this writing are unavailable for obvious reasons.

Will this system be a commercial success? It certainly has the required "gee-whiz" factor needed to get a customer's attention. Time will tell if consumers will come to judge the quality of a piano by whether it's self-tuning or not. Keep your eye on QRS's press releases in the months to come (<u>http://www.qrsmusic.com/Press/</u>). While the underlying technology isn't rocket science, the application of this technology is indeed clever.

Q&A with Don Gilmore

While discussing this system on the phone with Don, I was able to ask some common questions posed by myself and by others from related internet chit-chat:

Q. Should I delete my local tuner's phone number from my phonebook?

A. Undoubtedly this will reduce the number of times a tuner will visit your home. The system will faithfully replicate the factory tuning, but age and wear can make the piano detune enough to be out of the range of the device's control. Also the customer may wish to have the piano tuned to other than an Even temperament, and this can be done in their home and 'saved' by the system. Sometimes an 'alignment' tuning will be necessary, though the natural cyclical changes in a piano's tuning due to humidity are never more than 18-cents total deviation over an entire year.

Still, some tuning professionals appear to be intimidated. Bob Hohf, editor of "Piano Technicians Journal" said in an Editorial Perspective, "... the QRS system may be taken as an early warning that a change that will effect the tuning business is impending".

Q: Does the piano need to be plugged in and 'on' at all times?

A. Yes, if you want to play it, but it can be turned off when not used as it only takes 30-40 seconds to heat up and 'tune' itself. In fact, the system will automatically switch off after a period of playing inactivity.

Q. Will this draw much power and be expensive to run?

A. Not really. It has been shown that it only takes approx. 2 watts of power to flatten a string by about 30 cents (1/3 of a semitone), so that adds up to about 500-600 watts for the entire piano.

Q. Will I get shocked if I touch the wires, or otherwise cause damage if a metal object falls on the wires?

A. No - Don says the voltage applied to each wire is very low - from 0.2v-2.0 volts. If a direct shortcircuit is detected, only those wires will be disengaged from the system until the short is removed.

Q. If the different strings of a unison are tuned at different temperatures, won't that cause fluctuations in the sound after the initial hammer strike - due to the string's now differing elasticities? A. Don has noted that the unison wires can be at different temperatures, but hasn't noticed any unpleasant artifacts to his ear.

Q. How does the device tune the unisons without muting the adjacent notes?

A. Because there is a magnetic pick-up coil positioned over each string, it only 'sees' that string when it's doing its analysis. Because the string isn't "read" with the other strings in the unison, there's nothing to mute.

Q. Can the system compensate for strings that are flat when they're cold?

A. No - the system can only heat strings, thereby making them flatter. This is why the piano is tuned at the factory while the strings are at 95 degrees - they are relatively flattened or sharpened when it reaches your home by the application of more or less current - and therefore temperature. If you live in an extremely hot climate you would have your local tuner hand-tune the piano to be more sharp to compensate.

Q. In very cold environments, can the system apply enough power to the strings to sufficiently flatten them to A440 without overloading?

A. Pianos weren't meant to work very cold, but the system will call for as much current as is needed to achieve tuning. Power requirements are not linear with temperature, so a halving of room temperature does not cause the power demand to double. If there's too much demand, the system would shut down before it would hurt itself.

Q. Will periodic heating/cooling lessen the life-span of the wires?

A. Remember the nominal working temperature of the wires is 95 degrees-F. This isn't a lot of heat. As Don told me: "The keys in your pocket are warmer than the piano strings".

Q. Will I be able to 'store' more than one tuning profile?

A. Yes, in future models.

Q. Will the system dynamically tune the piano while it's being played?

A. No - you tune it once when the system is turned on, it stays where it is until the 40-second tuning process is done again.

Q. Are there any other applications for this device, such as tuning Harps?

A. This can be difficult as the brass agraffe or other components of existing instruments would need to be replaced such that each string is electrically isolated.

Q. Are there any plans to make this into a Kit to add on to existing pianos? A. Not at this time.

Q. How much will this system cost?

A. An article in the January 2 2003 issue of the "New York Times" quoted the president of QRS Thomas Doland as saying the device will first appear in ["Prelude" model] grand pianos rather than uprights because "... you don't want the tuning system to cost twice the value of the piano". From this statement one could interpolate that its initial retail price should be something less than twice the value of a standard Story & Clark upright. However, Don states that this was an unfortunate quote by Mr. Doland and that it's now estimated that the system should add only 10-25% to the total cost of a piano.

Q. Is the system visible or have any moving parts?

A. No. Electrical connections are made on the back of the pin block by a copper-clad printed circuit board with tiny circuit-connecting springs (like those in a flat-disc watch battery compartment) that touch the metal of the pin in the electrically isolated pin block that's made special for the piano. The copper traces lead to the edge of the pin block just under the agraffes where a ribbon cable is plugged in that leads to the power controller box.

Q. Won't the heating of the strings damage the wood of the piano over time? A. The infrared radiation effects are so small and broadcast over such a wide area that this is not possible.

Biography of the Inventor:

Don A. Gilmore, 39, is a project engineer and machine designer from Kansas City, Missouri. He received his B.S. in mechanical engineering from the University of Missouri-Rolla in 1986. He studied piano at the University of Missouri-Kansas City Conservatory of Music from 1972 to 1988 and has been a pianist for thirty years. He holds two U.S. patents and has two patents pending for various inventions relating to the music industry.

Glossary

- (1) Digital Low-Pass Filter: A single-chip device that allows low frequency signals to pass from it's input to it's output relatively unmuted, but stops higher frequencies from continuing along the circuit. The frequency at which this cut-off occurs is adjustable.
- (2) Microcontroller: An off-the-shelf microprocessor with memory and support circuitry all in one chip.
- (3) EEPROM: Electrically Erasable Programmable Memory that doesn't 'forget' it's settings after power has been shut off.

<Document End>