Libration Controller of Electromagnetic Vehicle Vibrator

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Abstract. Electromagnetic Vehicle Vibrator is a non-explosive seismic source, for high resolution detection of underground information, which is used for mineral resources reconnaissance and detecting special target underground abroadly. The work principle comes from Chirp radar technique, the main task is sending Chirp signal with strict controlled parameter to underground. The Chirp signal produced by Electromagnetic Vehicle Vibrator is sent to underground by power amplification and vibrator driven electromagnetism. So the quality of signal influences the whole performance index of seismic explosive system. This thesis discusses hardware and software of Electromagnetic Vehicle Vibrator.

1. Foreword
Seismic source is important part of seismic exploration technique, which is the source of seismic signal. The signal’s quality of seismic source affects effect of seismic exploration. There are many seismic sources, such as dynamite seismic source, gas acting seismic source, ball breaker seismic source, air gun seismic source, electrospark seismic source and vibrator and so on. Vibrator is a non-destructive seismic source, which is root in radar and sonar echo-ranging technique, is brought forward by Bill Doty and his tutor John Crawford in 1952 [1].

Vibrator deliver a time function relation excitation wave to underground by long time, which is by controlled little energy, long time excitation wave to realize great energy excitation produced by impact seismic source. It has excellences that using safety, using controllable wave to advance resolution, using correlation technique to suppress random disturbance, especially can be used in population and building thickness part which is not allowed to use dynamite seismic source, in city shallow engineering exploration haves broad appliance foreground, which develops appliance field of seismic perambulation. Vibrator driven by electromagnetism develops to vehicle with high-power and micromation, former is increasing detecting depth, while the latter solves detecting problems of architecture engineering quality. Electromagnetic Vehicle Vibrator adopts former thought, which is developed for increasing detecting depth.

2. Design of hardware of Electromagnetic Vehicle Vibrator
Function cell of libration controller includes CPU control, DDS sweep signal producing, alternation about human and manchine and power supply module (as figure 1). CPU take charge communion to human by LCD module and keyboard module, using Chinese display, realized by building word library in program memory of PHILIPS 89C58, E2PROM takes charge of access of parameters, adopting E2PROM 24C01 with I2C bus interface.
Signal occurring module is hardcore part of Electromagnetic Vehicle Vibrator, the signal of Electromagnetic Vehicle Vibrator is delivered to underground by power amplification and vibrator drived by electromagnetism. So the quality of signal influences the whole capability of system.

Because signal produced by vibrator is linear frequency modulation pulse, which is Chirp signal, it requests big time width, high frequency-modulation linearity, high stability and high reliability, but traditional methods can’t satisfy these requests. So adopting DDS signal producing module AD9852. Signal occurring module is formed by reference frequency source, AD9852 and lowpass filter and so on.

AD9852 is produced by ANALOG which adopt DDS technique( in figure 2). DDS is a frequency compose method which develops rapidly, it has advance nature with wide time width , short frequency conversion time, high frequency resolution ,series output phase, programmable and whole numeralization structure [5]. Work theory is by Nyquist sampling law to make a signal by sampling , quantification, coding , then forms a sine function table which exists in E²PROM , to change adding speed of phase accumulator by changing frequency control word, then sampling by certain frequency, the phase obtained is converted to amplitude array by phase-amplitude conversion. After D/A converter and lowpass filter, then sine signal is produced.
Sweeping signal circuit uses PHILIPS 89C58 as controller, pitches on AD9852 by coding, controls its working mode, signal frequency, amplifier and phase by data bus, address bus and control bus, then we can get sweeping signal. Because the voltage of microchip is 5V, while the voltage of AD9852 is 3.3V, changing voltage by logic electronic level changing, but output signal of AD9852 has direct current with 0.5V, by bandpass filter, taking out direct current and high frequency noise, the peak-peak value of signal is 600mv, which is delivered to power amplification after primary amplification.

We can set begin and end frequency of signal, and increment of frequency $\Delta f$, and this card can export signal with any wave appear, big frequency wide and amplification electing, which can be used in different seismic exploration situation.

3. Design of software of Electromagnetic Vehicle Vibrator
We introduce system’s flow by “pulse frequency modulation” module which is FM sweeping mode (in figure 3).

![Figure 3. System’s flow chart.](image-url)

Consumers incept sweeping signal’s parameter from import device: begin frequency(F1), end frequency(F2), sweeping time(D), frequency resolution and sweeping direction, after main program incepting parameters, if system’s clock is FS, by calculate expressions: $F_w = |F_1 - F_2|$, $N = D \cdot FS$, $\Delta f = F / N$, $F_w$ is sweeping frequency span, FS is system clock frequency, $\Delta f$ is the changing quantity of frequency in every clock cycle, $N$ is clock periodicity of frequency changing. We deliver data of every clock period phase changing to accumulator, and adding to the data of accumulator (capability of accumulator corresponds to a whole signal period). Output of accumulator can be used as the address of wave memory EEPROM (number in wave memory has direct ratio with cosine of address), output
of accumulator is change to voltage signal by DAC. So producing Chirp signal, key is the phase change of every clock period delivered to accumulator.

We can either use linearity sweeping inside, also can use non-linearity sweeping by outside. It can be pulse, also can be series wave. Δ frequency adopts complement of two, can be positive also can be negative, then can define sweeping direction of FM Chirp. If Δ frequency is negative (tiptop bit is high voltage), frequency sweeps from F₁ negatively (frequency decrease); if Δ frequency is positive (tiptop bit is low voltage), frequency sweeps from F₁ positively (frequency increase).

The range of signal output to vibrator is codetermined by the output of signal card and power amplifier, because power amplifier is not adjust blowing up multiple easily, so controlling range of signal by signal card, delivering expectant range when initializing sweeping parameters, confirming center range after setting frequency.

4. Experiment Result

![Figure 4. Result of time domain and frequency domain at 50Hz.](image)

Modulate frequency of Chirp signal of Libration Controller is from 1Hz to 5000Hz, when we use single frequency mode, frequency is 50 Hz, range is 8V, from sweeping process the signal’s time domain and frequency domain (in figure 4) we can see frequency of signal of libration controller is 50Hz, amplitude is 8V, frequency and amplitude is controlled exactly, which can be satisfied.

![Figure 5. Spectrum of scan frequency from 50Hz to 500Hz.](image)

Now in common use sweeping frequency in seismic exploration is from 50Hz to 500Hz, in sweeping course, frequency raises linearly, signal of Libration Controller is controlled exactly (in figure 5), sweeping with frequency interval is 1Hz, controlled phase precision is 0.1 rad, sweeping linearity ≤100μs, which satisfy technique target.
5. Conclusion
This paper enters on DDS technique, empolders Libration Controller hardware system, which can produce sweeping signal by system testing, Libration Controller can reach precision and other target of seismic signal, for advancing seismic collecting signal’s Signal-to-Noise, a sort of fashion is adding sweeping signal’s length, the more sweeping signal length, the more max of correlation, the higher of recording Signal-to-Noise. Time of sweeping signal is just a few seconds. Another is shaking in one point a few times, then adding times shaking, this fashion is similar to superposition profile of dynamite seismic source. In practice, the last fashion is always used. By testing, Libration Controller can reach repeating signal, which offers effective project to high resolution seismic detecting.

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