User’s Guide for

Model W200

Pulse Generator and Servo Amplifier

Overview

The Model W200 Pulse Generator and Servo Amplifier can be used as the core of a Mössbauer Spectrometer. Mössbauer Spectroscopy involves the resonant absorption of gamma rays\(^1\) and is more precisely named Resonant Gamma-ray Spectroscopy (RGS). For the isotope \(^{57}\text{Fe}\), the resonant absorption line width is approximately 1 part in \(10^{12}\) which equals the Doppler shift generated by a source velocity of 0.3 mm/s. The magnitude of the hyperfine interactions between the \(^{57}\text{Fe}\) nucleus and the surrounding electrons is on the order of \(10^{-7}\) eV or one part in \(10^{11}\) of the 14 keV gamma energy. A scan of the source velocity from -10 mm/s to +10 mm/s is large enough to sweep the gamma energy through the several possible resonances. The Model 200 controls the motion of a linear velocity transducer so as to provide a constant acceleration velocity sweep. The Model 200 also generates TTL digital pulses to cycle the memory address of a Multi-Channel-Scaler in synch with the source velocity sweep. The counts stored in a given channel of the MCS will correspond to a well-defined velocity value. The plot of the counts in each channel vs. the velocity associated with each channel is the Mössbauer spectrum.

Set Up

Figure 1 shows the connections between the W200C and the other components of the spectrometer. Table 1 lists the Input and Output connectors. Table 2 lists the controls and their functions. With all power off, especially the power to the High Voltage Power Supply, connect the components as shown in Figure 1. Turn on the power to the W200.

If the Velocity Transducer generates any audible noise, turn off the W200 immediately and see instructions below for adjusting the bandwidth and gain of the servo amplifier.

---

\(^1\) Named after Prof. Rudolph Mössbauer, the discoverer of recoilless resonant emission and absorption of gamma rays. See [http://nobel.sdsu.edu/physics/lauerges/1961/mossbauer-bio.html](http://nobel.sdsu.edu/physics/lauerges/1961/mossbauer-bio.html)

\(^2\) The historical name “gamma ray” was given to photons generated by nuclear transitions, in contrast to X-rays which are photons generated by electronic transitions.
The servo amp controls the motion of the velocity transducers motor shaft. The bandwidth, gain and offset controls should have been previously adjusted for optimum performance. The displayed Vref and Vpu signals on the oscilloscope should be the same within 2%, i.e. the peak-peak amplitude of Verror should be approximately 2% or less of the peak-to-peak amplitude of Vref. Once the W200 is controlling the motion of the source and generating the SSP and CAP pulses, set the SCA window and then start the MCS to record the Mössbauer spectrum of your sample. The use of the MCS, proportional counter and HVPS are not cover here.

Figure 1. Layout of a Transmission Mode Mössbauer Spectrometer using the Model 200C Pulse Generator and VT Controller
### Table 1: Connectors

<table>
<thead>
<tr>
<th>Signal</th>
<th>Connector Type &amp; Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP</td>
<td>BNC, Rear Panel</td>
<td>Start Sweep Pulse (TTL output)</td>
</tr>
<tr>
<td>CAP</td>
<td>BNC, Rear Panel</td>
<td>Channel Advance Pulse (TTL output)</td>
</tr>
<tr>
<td>Vdrive</td>
<td>9-pin sub-D, Rear Panel</td>
<td>Motor Drive signal (analog output)</td>
</tr>
<tr>
<td>Vpick-up</td>
<td>9-pin sub-D, Rear Panel</td>
<td>Motor Velocity Sensor Pick-Up (analog input)</td>
</tr>
<tr>
<td>Monitor</td>
<td>BNC, Rear Panel</td>
<td>Servo Amp Monitor Output (analog output) Selected by Monitor Switch on front panel (see below).</td>
</tr>
</tbody>
</table>

### Table 2: Controls

<table>
<thead>
<tr>
<th>Control</th>
<th>Type and Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Switch</td>
<td>Single throw toggle on front panel.</td>
<td>Switches +/- 12 VDC from NIM BIN PS</td>
</tr>
<tr>
<td>Scale</td>
<td>10-position thumb wheel switch on front panel</td>
<td>Scales Vref by 0 to 9.</td>
</tr>
<tr>
<td>Monitor</td>
<td>Four-position rotary switch on front panel</td>
<td>Selects internal analog single to route to BNC jack on rear panel. Choices are: Vref = Triangular velocity reference waveform after filtering and scaling. TP2 on schematic. Vpu = Signal generated by velocity transducer’s velocity sensor after amplification and filtering. TP1 on schematic. Verror = (Vpu - Vref) TP5 on schematic. Vdrive = Voltage applied to velocity transducer drive coil. J1, pin 7 on schematic.</td>
</tr>
<tr>
<td>BW</td>
<td>25-turn potentiometer on front panel</td>
<td>Controls high-frequency roll of servo amp.</td>
</tr>
<tr>
<td>Gain</td>
<td>25-turn potentiometer on front panel</td>
<td>Controls low-frequency gain of servo amp.</td>
</tr>
<tr>
<td>Offset</td>
<td>25-turn potentiometer on front panel</td>
<td>Controls DC offset of input to Gain and BW amplifier. (This is not the offset of Vdrive.)</td>
</tr>
</tbody>
</table>
**W200 Function**

The relationships of the start sweep pulse (SSP), the channel advance pulses (CAP), the digital reference waveform \(D_{\text{ref}}\) and the analog reference waveform, \(V_{\text{ref}}\), are shown in Figure 2. An embedded, custom-programmed micro controller performs the digital functions of the W200. The CAP pulses are generated as a free running clock with a period of 50 \(\mu\)s. The CAP pulses are routed to the Channel Advance input of the external MCS and to an internal up/down counter. This counter is set to count up from 0 to 511, then down to 0 and repeat. Every time the counter reaches 0, a SSP pulse is generated. The SSP pulse is routed to the Start Sweep input of the external MCS. The 9-bit binary output of the counter is \(D_{\text{ref}}\) and is routed to the input of a digital-to-analog converter (DAC). The output of the DAC is routed to the reference input of the analog servo amplifier\(^3\).

The reference signal is scaled and filtered on the analog circuit board of the W200. The schematic of the analog servo amp is shown in Figure 4. This scaled and filtered signal is \(V_{\text{ref}}\). Similarly, the amplified and filtered velocity sensor input signal is labeled \(V_{\text{pu}}\). The signals \(V_{\text{ref}}\) and \(V_{\text{pu}}\) are input to a difference amplifier whose output is \(V_{\text{error}}\). \(V_{\text{error}}\) is then amplified and filtered and used to drive the motor shaft. The motor drive coil, the motor shaft, the pick-up sensor and the amplifiers U1A, U1B, U4B U7A, U7B and U8 form a negative feedback loop. The drive signal, \(V_{\text{drive}}\), is the product of \(V_{\text{error}}\) and the gain of U4B, U7A, U7B and U8. The larger the gain is, the smaller \(V_{\text{error}}\). As discussed below, there are limits to how large the servo amplifier gain can be.

Figure 3 shows the relationship of the acceleration, \(a\), velocity, \(v\), and displacement, \(x\), of the motor shaft and source. Also shown is the drive force required to achieve the desired motion. A constant acceleration provides the desired linear velocity sweep. The resulting displacement is parabolic. There are two pertinent forces acting of the motor shaft: 1) the force generated by the drive coil and 2) a restoring spring force generated by the flexure plates that support the shaft. The drive coil force, \(F_d\), is proportional to \(V_{\text{drive}}\). The spring force is \(- kx\). If \(m\) is the mass of the moving shaft-source assembly, then the net force on the shaft is given by

\[
F_{\text{net}} = ma = F_d - kx
\]

Solving for \(F_d\),

\[
F_d = ma + kx
\]

The drive force and \(V_{\text{drive}}\) are the sum of a square wave and the parabolic displacement. Confirm this by observing \(V_{\text{drive}}\) on the oscilloscope via the Monitor output.

\(^3\) A servo amplifier is a device that tries to force an actuator to follow the input reference signal. A common example of such a control loop is the thermostat and furnace in a house.
Adjusting the Gain and Bandwidth of the Servo Amplifier

If the gain and bandwidth of the servo amplifier are set improperly, the system can break into oscillation. The control function of the servo amplifier is stable as long as the phase shift around the feedback loop is 180°. However, if at a given frequency the phase shift is 360° and the loop gain is unity or larger then the system will oscillate. At first glance, the only phase shift is the 180° shift introduced by connecting the sensor signal to the negative input of the difference amplifier. This is a good approximation as long as the phase shifts introduced by the other components in the loop are small. The operational amplifiers used in the W200 servo amplifier are limited to individual maximum gains of ten or less. The associated phase shifts are small up to 100 kHz. However, the mechanical system of the drive coil and sensor coil connected by the motor shaft is not perfectly rigid. At approximately 10 kHz the motion of the sensor coil will be out of phase with the drive coil due to the motor shaft compressing and expanding. If the gain of the electronic system is too large at this frequency the motor will oscillate and emit a high pitch whistle. The oscillation can be observed in the Vpu or Verror signals. To suppress this oscillation, decrease setting of the Bandwidth and/or Gain controls.

The high frequency gain is controlled by the Bandwidth control on the front panel of the W200. The Gain control sets the frequency independent gain. If the Bandwidth control is set too low, the phase shift across op amp U7A will be significant at lower frequencies and the system will oscillate at approximately 400 Hz. The sensitivity of the system to the setting of the Bandwidth control will depend of the setting of the Gain control.

To adjust the Bandwidth and Gain controls to the best compromise, observe the Verror signal and increase the Gain until the system oscillates. Then reduce the Gain by rotating the Gain control until the oscillation stops. Then reduce the Gain control 1 or 2 more revolutions. Increase the Bandwidth control until the high frequency oscillation is observed. Then reduce the Bandwidth control, noting the number of turns, until the low frequency oscillation is observed. Set the Bandwidth control midway between the low frequency and high frequency oscillation limits. Increase the Gain again until the system oscillates and then reduced the Gain 1 or 2 revolutions. This procedure should minimize the magnitude of Verror and make the system stable.
Figure 2  Time dependence of CAP, SSP, MCS memory address, Dref and Vref. Number of Channels is 1024 and Dwell Time is 0.05 ms.
Figure 3  Time dependence of source (A) acceleration, (B) velocity and (C) displacement. Also, shown is (D) Vdrive, the voltage applied to the drive coil.
Title: Analog PID Servo Controller
Project: W200
Part #: pcb1

Date: August 16, 1999
Drawn by: T. Kent
Last revision: Sept. 6, 2001
File: W200cpsu.fcw

Parts List:
U1-U7: TI TL062 duals, 8 pin DIP
U8: OPA547, 7 lead stagger-formed TO-220

All resistors are 1/4 watt 1% metal film, e.g. Digi-key Part No. 10.0KXBK

Notes:
1. All op-amp V+ and V- power pins bypassed to ground with 0.01 uf caps
   Digikey # BC1078CT (lead spacing 2.54 mm)
2. Board length 9.50" (not 9.55") TK 2/9/01