AF-902/AF-904® Generation II Digital FSK Track Circuit

General Information

ASTS USA’s AF-902/AF-904® Generation II (AF-Gen II) Series Digital FSK Track Circuit systems provide unmatched capabilities for train detection and delivery of complex train control data to moving transit vehicles. As a result, these systems are ideal for management of heavy mass transit traffic with close operating headways, and provide the highest measure of system reliability for advanced functions such as driverless operation. AF-Gen II track circuits are much simpler to install, calibrate and maintain than earlier AF-based systems and require far less of the massive and complex ground material and interfaces if these other systems.

AF-Gen II builds upon the success of ASTS USA’s original AF-900 Series Track Circuit with new design features and communications technologies/capabilities. For example, AF-Gen II provides several new Ethernet-based features such as peer communications with MicroLok II, integral Web server user interface and SNMP remote monitoring.

All of the track interface equipment from the original AF-900 Series Track Circuits is retained with the AF-Gen II system. In addition, the new system’s cardfile PCBs can be installed in any existing AF-900 Series unit. Combined with ASTS USA’s other cutting-edge train control products (MicroLok® II wayside and MicroCab® carborne), the AF-Gen II enables ASTS USA to offer a full-spectrum mass transit Automatic Train Control (ATC) system adaptable to the most demanding needs of any transit operation.

Advantages

Basic System

- Provides responsive train detection and wide-spectrum cab signal communications;
- Redundant design for continuity of operation and maintenance of headways;
- Essential to advanced operations such as driverless ATC;
- Requires no insulated joints on mainline or station tracks;
- Provides sharp, stable track circuit definition;
- Two or four track circuit (cardfile) options;
- Only two basic types of PCBs required for all applications;
- New AF-Gen II PCBs can be retrofitted into existing AF-900 Series Cardfile;
- Highly dependable and flexible digital FSK communications in the rails;
- Permits delivery of diverse cab signal commands;
- Simple on-site set-up configuration and tuning procedures;
- Track Cable Bonds greatly simplify system connections to rails;
- Highly adaptable operating software, allowing future derivatives to be tailored to customer needs.
- Unaffected by current incursions caused by broken rails, absent or defective bonding, sand, rust, leaves, etc.;
- Shielded against false pick-ups caused by propulsion noise;
- Immune to effects of DC propulsion imbalance;
- Does not require transpositions, balancing loops, etc. to balance rail resistance (tolerates 100% propulsion imbalance without disruption or degradation);
- Immune to improper operation due to crossed or grounded wires or influences such as capacitive and inductive coupling or stray currents;
AF-Gen II: “AF-904” Style General Application:
Non-redundant Control of Four Track Circuits

AF-Gen II: “AF-902” Style General Application:
Redundant Control of Two Track Circuits
Advantages (cont’d)

- Unaffected by conducted and inductive emissions from alternating current (AC) variable drive vehicles;
- Minimal auxiliary equipment:
  - No need for L-C tuned decoders or loading capacitors distributed along track circuit;
  - Does not require phase-shifting devices on very short or very long track circuits;
  - No requirements for vane relays, track transformers, lightning arrestors, resistors, balancing impedances, insulated joint couplers, filters or fuses.

Ethernet and User Interface: Features and Capabilities

- Optional singular or redundant Ethernet interface to MicroLok II.
- Ethernet interface provides 5-bit speed code data.
- Integral Web server provides enhanced user interface.
- Web server permits Internet Explorer access to all calibration and data storage functions.
- SNMP-based remote monitoring permits real-time observation of system’s operating parameters.
- SNMP “trap” messages issued if system errors detected.
- Single Track Circuit System (TCS) PCB combines functions of original CPU and Auxiliary boards.

Basic Track Cable Bond Configuration

System Application

The AF-Gen II Track Circuit is typically part of an Automatic Train Control System (ATC), providing both train detection and transmission of digital cab signaling data for the Automatic Train Protection (ATP) function of the ATC. Track circuits served by this system include mainline, station areas, turnouts, crossovers, storage yard and highway crossing zones. Major components of the AF-Gen II Track circuits include a System Cardfile, Track Coupling Units and a track Cable Bond. In the “AF-902” style Track Circuit application, the System Cardfile typically uses two redundant subsystems to control two track circuits in driverless train control systems. In the “AF-904” style Track Circuit application, the system typically uses four non-redundant subsystems to control up to four track circuits in driver-operated train control systems.

AF-Gen II Track Circuits serve specific track circuits along the transit line and are locally managed by track-dedicated ASTS USA “Track” MicroLok™ II units. (Other “Interlocking” MicroLok II units handle standard interlocking functions such as control and monitoring of switch machines and wayside home signals.).

The Track MicroLok II units generate vital messages (train speed/direction, next carrier transmit frequency, track circuit ID etc.) for the vehicle’s MicroCab™ cab signal system, using the AF-Gen II equipment as the digital communications medium. Other messages between the AF-Gen II system and the Track MicroLok II unit include any temporary local speed restrictions and the health of the track circuit. Between interlockings, train detection indications can be sent via a standard serial communications link or using a new Ethernet-based system configuration.

Typical Cab Signal Direct Injection At Crossover
**Typical Rack Installation of AF-900 Cardfiles**

**System Application (cont’d)**

At interlockings, train detection signals from the AF-Gen II system are routed directly to parallel channel inputs on the interlocking MicroLok II units to speed delivery of shunting indications for interlocking over-switch functions. No track relay is needed for these detection functions.

In storage yard applications, AF-Gen II Track Circuits allow automatic movement of cars for the purpose of making up new trains. The equipment is well suited for short track circuits/slow car movements in the yard, and serves as a highly cost-effective alternative to a system of expensive vane relays.

In highway crossing zones, the AF-Gen II Track Circuit eliminates the need for audio frequency overlay track circuits to control highway crossing warning systems. The system is designed to permit application to crossing approach and island circuits.

Signals and messages in the rails are communicated to and from the AF-Gen II cardfiles via simple but highly effective Track Cable Bonds, consisting of a specified length of heavy (e.g. 350 or 500 MCM) cable connected/arranged between the rails in “S”, “O” or “I” arrangement as required by the location. Insulated rail joints are not required at mainline or station locations.

At crossovers, turnouts and other areas with high metal content, standard cab loops are used to pass cab signaling data to the rails.

AF-Gen II Track Coupling Units are used to bridge signals between the System Cardfile and the Track Cable Bonds or Cab Loops. These units are tuned to the carrier frequency and provide impedance matching to/from the track. Refer to RSE-1F2 for additional details on AF-Gen II Track Circuits major components.

**Basic System Operation**

Each AF-Gen II system vitally monitors the status of one track circuit. An FM, audio frequency carrier is transmitted at one end of the track circuit and received at the other. This carrier is modulated in a binary manner to generate digital cab signal data for the train. Carrier level and a part of the digital message is monitored by the receiver to determine track occupancy.

**Train Detection**

A key function of the AF-Gen II Track Circuit is to detect the presence of a train in the monitored track circuit; this information is processed by the Interlocking MicroLok II system. Train detection is accomplished in the AF-Gen II System Cardfile by measuring the amplitude of the digital track signal used to deliver data to the vehicle’s cab signal equipment. This signal is continually transmitted from the other end of the track circuit with one of eight possible carriers. The Track MicroLok II system determines the vehicle’s direction of travel and which AF-Gen II units will function as transmitters and receivers.

While the track circuit is unoccupied, the receiving AF-Gen II circuits continually check the incoming message for proper signal threshold and accuracy. Comparison is made with the signal sent by the AF-Gen II transmit circuits. If a message is received, but fails accuracy checks, the AF-Gen II unit notifies the Track MicroLok II system of the presence of a train.

When a train shunts the rails of the monitored track circuit, the signal is blocked; this condition is recognized by the receiving AF-Gen II track circuits as a drop below a preset signal threshold, and is reported to the associated Interlocking MicroLok II system. While the shunting train bridges adjacent track circuits, both are reported as occupied. When the train clears a track circuit, the received signal threshold is restored; the AF-Gen II system responds accordingly.

The AF-Gen II Track Circuit equipment includes many vital features designed to eliminate missed track occupancy conditions and false occupancy indications. For example, each track circuit has a unique digital I.D. number, while different signal carrier frequencies are selected for adjacent and parallel track circuits to help minimize cross talk between these circuits. The design and function of the Track Cable Bond also minimizes false occupancy readings, and staggering of track circuit polarities is not required.

Because the AF-Gen II Track Circuit continually monitors the signal carried in the rails, it also provides for broken rail detection.
Cab Signal Data Transmission

One of the major strengths of the AF-Gen II Track Circuit is its extensive cab signal data transmission capability, made possible through Binary Frequency Shift Keying (BFSK) modulation. A typical set of cab signal data elements includes:

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Speed</td>
<td>Maximum speed permitted within track circuit target</td>
</tr>
<tr>
<td>Target Speed</td>
<td>Desired speed at track circuit target</td>
</tr>
<tr>
<td>Distance-to-Go</td>
<td>Distance to target speed</td>
</tr>
<tr>
<td>Next Frequency</td>
<td>Carrier frequency of the next track circuit</td>
</tr>
<tr>
<td>Track Circuit ID</td>
<td>Identification of present track circuit</td>
</tr>
<tr>
<td>Berthed (Door Open)</td>
<td>OK to open vehicle doors at station</td>
</tr>
<tr>
<td>Current Direction</td>
<td>Train direction of travel (E or W, N or S)</td>
</tr>
<tr>
<td>Change Direction</td>
<td>Reverse train direction of travel</td>
</tr>
<tr>
<td>Couple/Uncouple</td>
<td>Couple/uncouple cars during train consist make-up</td>
</tr>
</tbody>
</table>

For example, Line and target speed commands could range from 0 to 65 mph in 5 mph steps plus additional speeds of 8 mph and 1 mph. Isolation of commands between track circuits is accomplished by alternating eight available data carrier frequencies (also used for train detection). A typical range of frequencies is 9.5 to 16.5 kHz in 1 kHz steps and are numbered FO through F1. On a double-track E-W or N-S right-of-way odd-numbered frequencies are assigned to west (or south) bound track circuits, while even-numbered frequencies go east (or north) bound track. This alternating configuration helps assure the required isolation.

In this sample configuration, carrier F1 contains data that informs the train of the next cab signal frequency (F3). On board the train, one receiving filter is tuned to F1 and the other to F3. As the train approaches the Track Cable Bond, signal F1 drops out. Once valid data and level is detected on F3, the vehicle logic ignores the data arriving from the F1 receiving filter. The new data is then decoded and the vehicle logic re-tunes the receiving filter (that was tuned to frequency F1) to the next cab signal frequency in the sequence of track circuit frequencies.

User Interfaces (PC or PCB Front Panel Accessed)

The new AF-Gen II TCS board front panel contains two Ethernet ports. Each of these ports accommodates peer-based AF-GenII/MicroLok II communications, SNMP-based remote monitoring and Web server-based user interface. The Web server provides a convenient way to monitor system operation, as well as configure and calibrate AF-Gen II system operating parameters using Microsoft's Internet Explorer. All front panel operations can be performed using the Web interface.

In addition to Ethernet-based access, the TCS board front panel (see RSE-1F2) can also be used to manually modify and display vital and non-vital parameters, as well as to calibrate and configure the AF-Gen II system.

Typical Configuration of Cab Signal Track Circuit Frequencies
In addition to Ethernet-based access, the TCS board front panel (see RSE-1F2) can also be used to manually modify and display vital and non-vital parameters, as well as to calibrate and configure the AF-Gen II system.

Among the functions observed/controlled from the TCS are track transmission direction (E or W), internal failover status, system health (“self” and “partner”), MicroLok II communications status and block speed (local or remote). Refer to RSE-1F2 for additional details of the various AF-Gen II user interfaces.

**Network and Serial Communications**

With the incorporation of network-based communications, AF-Gen II systems can be configured for remote communications with other systems in a variety of ways (see diagrams). For example, an AF-Gen II unit can be accessed from a remote PC configured to monitor SNMP messages.

The PC is linked to the unit via a Router and an Ethernet switch. The Router can also act as a DHCP server to give IP addresses to several local PCs.

Likewise, a local (e.g. laptop) PC can be linked to an AF-Gen II unit for Web tool access. This PC can obtain a network address from a DHCP (if available), or manually configured for the network. In this instance, the address of the AF-Gen II hardware can be obtained with a discovery tool or manual input. In this configuration, all hardware on the network can be accessed. Note: Ethernet communications is only required if SNMP monitoring or use of a web-based interface is desired.

In the above-described system, standard RS-485 serial communications can still be used to connect the AF-Gen II cardfiles to the controlling Track MicroLok II.

(Continued on page 8.)
AF-Gen II also allows for fully peer-based communications with PCs (local and remote) and the Track MicroLok II unit, using both redundant and non-redundant peer configurations. In the redundant configuration, dual Ethernet switches are used to route both PC and MicroLok II communications with the AF-Gen II unit(s).

In the non-redundant configuration, a single Ethernet switch serves manages PC and MicroLok II messages with the AF-Gen II unit(s).
System Specifications (Typical/Application Dependent)

Track Circuit
- T.C. Length: 1000 ft./305m (max.), 65 ft./19.8m (min.)
- Shunt Sensitivity: <0.25 ohms ballast
- Pre/Post Shunt: <5.0 ft./1.52m

FSK Communications
- Carrier Freq.: 9.5, 10.5, 11.5, 12.5, 13.5, 14.5, 15.5, 16.5 kHz
- Modulation: Binary Frequency Shift Keyed carrier (BFSK)
- Baud Rate: 200 BPS
- Shift: +200 Hz
- Bandwidth: 500 Hz

Serial Communications from “Track” MicroLok II
- Sig. Message: 24 data bits, 8 header bits, 8 address bits, 24 CRC validation bits
- Protocol: ASTS USA vital serial link
- Parameters: Direction, Next Frequency, Target Distance-to-Go, Line Speed, Berthed, Couple/Uncouple, Birfurcation

Serial Communication to “Track” MicroLok II
- Parameters: Block Speed, Standby Health, Track Occupancy, Correspondence

Cab Signal Data Transmitted to Train (Via Track)
- Cab Message: 37 data bits, 8 header bits, 12 CRC validation bits
- Protocol: Synchronous, Bit-Oriented
- Encoding: NZRI
- Parameters: Track Circuit ID, Primary/Backup, Direction, Next Freq., Distance-To-Go, Line Speed, Target Speed, Berthed (Door), Couple/Uncouple, Birfurcation

Peer Communications Received from “Track” MicroLok II
- Sig. Message: 26 data bits, 8 header bits, 8 address bits, 24 CRC validation bits
- Protocol: ASTS USA MicroLok II Peer Message Protocol
- Parameters: Direction, Next Frequency, Target Distance-To-Go, Line Speed, Target Speed, Berthed, Birfurcation, Couple/Uncouple, Remote Block Speed

Misc.
- Speed Commands: 65 to 0 mph in 5 mph steps, additional: 1 mph, 8 mph
- Blocking Speeds: 0, 1, 5, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 mph
- Track Circuit ID No.: 0 to 4095

Ordering and Additional Information
- To order individual components for AF-Gen II Track Circuits, refer to RSE-1F2.
- For additional technical details on the AF-Gen II system, request ASTS USA Service Manual SM-1F2.0001
- For additional information on AF-Gen II Digital FSK Track Circuit applications possibilities, contact your ASTS USA Account Executive.