HIGH PERFORMANCE SWITCH SYSTEM

powered by the

HIGH PERFORMANCE SWITCH ACTUATOR

and the

‘POWERLINK’ BACKDRIVE

presented by

IAD
Rail Systems
A Claverham division

SYNOPSIS

It is widely recognised and well documented that one of the top two infrastructure causes of train delay in the UK rail network is the ubiquitous "points failure". Network Rail has established that on a national basis the average failure rates of existing electro-hydraulic and electro-mechanical Points Machines are 0.85 years and 1.3 years per point end respectively. Network Rail data also shows that in the worst locations, existing equipment fails at a much higher rate than this and can lead to major delays, particularly at key junctions where the "domino effect" in terms of consequential train delays and hence passenger upheaval can be extreme.

Despite a number of initiatives by the rail industry to reduce "points failure", it remains a serious problem for the simple reason that Points Machines currently in service in the UK rail network do not have the inherent systematic reliability that will allow improvement in the performance of the infrastructure. In short, symptoms rather than causes have been treated.

Despite current short term problems within the industry, projections show significant increases in rail traffic, in terms of train and passenger numbers, year on year. These increases will be accompanied by higher line speeds and axle loadings, with the track utilised for a higher proportion of the time, resulting in a significant decrease in time available for maintenance activities to be carried out. These projections, coupled with Network Rail's desire to implement a highly reliable, low maintenance railway, have created a major demand for new technologies to be available now in order to sustain this objective.

The **High Performance Switch System, HPSS**, which has gained Product Acceptance from Network Rail, is therefore available now for the railway of the 21st century. It is a technically advanced, fully integrated system, offering major advances in Switch Actuation technology and is designed to provide exceptional operational performance in terms of Reliability, Availability, Maintainability and Safety (RAMS). It comprises all elements of actuation, lock and detection of the Switch Rails, and is made up of the following fully integrated sub-systems:

High Performance Switch Actuator (HPSA)
a robust electro-mechanical in-sleeper Points Machine, with built-in Condition Monitoring.

'PowerLink' (Torsional) Backdrive
a supplementary drive system mounted in the four foot, with in-sleeper stretcher bars and supplementary detectors.

The generic term "points failure" covers a multitude of sins, and is usually the result of the old rail industry tradition of designing Track and Signalling systems as separate entities, without full consideration of the interfaces and interactions between the two. As a result, points failure is often a consequence of the inability to maintain Switches and Crossings (S&C), the age of existing designs, and design weaknesses that have never been resolved satisfactorily.

Existing points set-ups, and in particular Points Machines, detectors, and backdrives, are therefore susceptible to a number of inherent failures, the majority of which become more frequent with increased levels of rail traffic, heavier axle loads, and higher line speeds.

The HPSS has been designed to offer the UK rail infrastructure a step-change in RAMS performance, introducing a number of highly innovative technical features to the railway:

- **Designed for 25 year service life, with zero scheduled maintenance**
- **Switch Rails driven to stall against Stock Rails, eliminating any gap or the need to adjust the stroke of travel, and compensates for wear**
- **Use of d.c. brushless motor technology, provides high power density**
- **Secure locking system, utilising a non-backdriving leadscrew with duplex brakes**
- **Continuous rail position detection and lock detection with vibration tolerant, non-wearing, non-adjustable sensors**
- **Built-in Condition Monitoring of key operational parameters provides a real time status of system "health", thus allowing trend analysis to be carried out**
- **Use of a handheld computer for ease of commissioning and fault-finding**
- **Allows machine tamping of whole switch and crossings**

HPSS has been designed to eliminate an estimated 65-70% of existing points machine failures, thus significantly reducing the associated train delays.

Business Case analysis shows that break-even on investment by the railway will be just over 3 years, and over a 25 year service life will save tens of millions of pounds in train delays.

The inherently high reliability and correct use of "Reliability Centred Maintenance" systems to assist with preventative maintenance could ultimately allow the HPSS to approach the 100% Availability target, which has to be the goal for any modern rail system, and in particular new flagship projects such as Network Rail's West Coast Route Modernisation.

The HPSA point machine and the 'PowerLink' Backdrive have been developed by IAD Rail Systems, a division of Claverham Ltd, who have many years experience designing safety critical actuation systems.

HPSSs Installed At Nunhead Junction (Railtrack Southern Zone)

Network Rail FRAME data shows that 80% of the total train delay minutes caused by points related problems are attributable to 5 major categories:

- Electro-hydraulic points systems
- Electro-mechanical points systems
- Track conditions
- Backdrives
- Points fittings

Detailed below is a list of the most commonly occurring failure modes of existing points, all of which relate to one or more of the above categories . Alongside each failure mode is evidence of how the HPSS has been systematically designed to eliminate or significantly reduce the impact of such failures.

Regular Failure Modes: Existing Points	**Integrated System Solution: HPSS**
Hydraulic failures or leaks	No hydraulics used (HPSS is an electro-mechanical system)
Motor failures, brushes wearing out	Utilises d.c. Brushless Motor, high power density, no overheating, watertight design
Failure of Microswitches (detectors), including contact bounce (bobbing detection)	No microswitches used (HPSS detectors are non-contact devices)
Wear of Safety Critical mechanical components	Design accommodates any wear occurring during 25 year life without deterioration of function or safety
Rail position detection and lock detection going out of adjustment (Facing Point Lock)	No adjustments are necessary once system is commissioned; system drives to stall for each switch movement, thus eliminating the gap between Switch and Stock Rails, and automatically compensates for wear
High Friction (poorly lubricated slides)	System designed to have sufficient force reserves to overcome high friction levels Use of low-friction slide inserts
Obstructed points	High stall force allows majority of obstructions to be overcome
Flooding	System designed to withstand submersion in one metre of water (IP67 specification)
Switch Rail creep	HPSS tolerant of creep
Extremes of temperature	System insensitive to variations in temperature
Overheating of electrical components	Power and time of operation controlled by system Electronic Control Unit
Inability to fully tamp the S&C	HPSS allows full machine tamping
Damage to equipment during tamping e.g. broken stretcher bars, linkages	All equipment housed inside covered metal bearers; all cables routed through bearers

Development of HPSS commenced in 1994, and since that time the design has gone through a number of iterations commencing with a comprehensive and carefully structured requirements capture. This was devolved into system and sub-system technical specifications, which were followed by mathematical modelling and analysis, sub-system qualification testing, system integration testing and an in-track trials programme. These activities formed the basis of the extremely arduous and comprehensive Safety Approval programme, conducted under the auspices of Railtrack's (and subsequently Network Rail's) Product Acceptance regime and in accordance with the requirements of the UK rail industry's Engineering Safety Management System (known as the "Yellow Book").

The prototype HPSS, known as the Switch Actuation Mechanism (SAM), was designed and developed to the requirements of Railtrack's draft Performance Specifications, the ES3200 series. The ES3200 specifications were produced as a set of performance based requirements to allow Switch and Crossing designers to produce innovative solutions for high speed, highly reliable systems, rather than being prescriptive in the definition of the design construction.

The top level ES3200 Specifications were devolved by the HPSS Project Team into sub-system and component specifications, ensuring that all key interfaces and interactions of the system were captured.

Failure modes of existing Points Machines were identified and documented, and these were seen to be major design "drivers" for the new system. Using this technique, the project team ensured that known contributory factors to points failure and hence train delay were designed out, or at worst reduced to an acceptable level.

To assist with the identification of failure modes, and in particular those affecting the safe operation of the S&C, a comprehensive Hazard Identification was carried out. This ensured that all known hazards associated with generic S&C systems were formally logged and addressed by the HPSS design.

The SAM Design was produced using a systematic approach that took account of all hazards within the Hazard Log. Design analyses included performance calculations, stressing, Failure Mode and Effects Analysis, Failure Mode Effects and Criticality Analysis and Fault Tree Analysis.

Qualification Testing

To demonstrate fitness for purpose and compliance against Railtrack's Specification, the HPSS and its sub-systems, notably the HPSA, have been subjected to a comprehensive Qualification Test Programme. All testing has been carried out against test specifications and procedures that have been reviewed and endorsed by Railtrack and Network Rail appointed Independent Safety Assessors. The following key tests have been carried out:

Endurance: The prototype system was used to carry out over 360,000 switch operations to prove that the design is robust and will operate on demand for its entire service life with no significant wear or degradation. This work was completed on an EV Full Depth panel in an off-track, non passenger carrying site at Yatton station near Bristol.

Fatigue: Tests were carried out to prove that the system will withstand the cyclic loading from rolling stock for its prescribed life, and will not suffer premature random failure. In excess of 3 million applications of vertical and lateral loading, replicating train axle loads, have been applied to the HPSA unit with no degradation or failure.

Vibration: These tests were carried out to ensure the HPSA unit would withstand the levels and frequency of vibration likely to be experienced in-track. Tests included resonance searches in all 3 axes and vibration endurance. Additional tests have been carried out on the key safety critical sub-assemblies (rail detectors, brakes and the Electronic Control Unit) to ensure robustness of design and that there are no unsafe modes of failure due to vibration.

Electro-Magnetic Compatibility (EMC): A comprehensive suite of EMC tests were carried out to demonstrate compliance with Railtrack's Requirements. The Test Specification was written in conjunction with a Specialist with extensive experience including work on the Channel Tunnel. Tests carried out include those to demonstrate the system's suitability for use in DC third rail applications and overhead line applications.

Additional EMC tests have also been carried out in the "live" railway environment (Beckenham Junction, Southern Zone). The entire Actuation, Locking and Detection sub-system components were exposed to live 3rd rail whilst specific types of rolling stock, known to produce extreme electro-magnetic emissions, were using it. No adverse effects were identified at any time during testing in an extremely arduous electro-magnetic environment.

Water Submersion: HPSA unit was submerged in water up to sleeper level and unit functionally tested. The Electronic Control Unit, Motor, Gearbox, Brake and Sensors are all IP67 rated (i.e. rated for submersion to 1 metre), which ensures continued system availability even during and following extreme flood conditions.

Contamination: Functional tests have been carried out with the unit subjected to extreme levels of dust and ballast being introduced into and over the system.

Hot And Cold Extremes: Functional testing of the HPSA unit has been carried out at minus 20 degrees Celsius to plus 60 degrees Celsius. Tests have also been conducted to check that no adverse effects result from temperature shock caused by sudden cooling.

System Integration: A full DV Shallow Depth Switch System including the HPSA, Torsion Backdrive and Supplementary Detection, was assembled at Balfour Beatty Rail Engineering's Sandiacre site. Tests were carried out to verify form, fit and function, including interfaces with power supply and signalling relays, prior to installation at Nunhead Junction (Southern Zone).

In-Track Performance

The ultimate demonstration of performance of the HPSS has been to undertake an in-track prototype trial, followed by pilot operation of the productionised system. In both instances, key operating and safety parameters were monitored in order to validate system performance against predetermined Success Criteria agreed with Railtrack's Infrastructure System Review Panel.

Prototype Trial: The prototype Switch and Crossing system, including the Switch Actuation Mechanism (SAM) was installed in the West Coast Main Line at Tamworth 33 Points on 26th April 1998. A fully monitored in-track trial was conducted for 23 months, finishing on 1st April 2000, during which time the system operated satisfactorily, with no failures resulting in unsafe operating conditions.

During the trial period more than 70,000 trains passed over the S&C System, averaging 100 per day at speeds up to 105 mph. Over the same period the SAM operated the points 28,000 times, averaging 40 times per day.

The results of the trailing point trial taken together with other lessons learned during the SAM development provided the basis for the development of the current Production Standard HPSS.

Production Pilot Installation: A pair of production HPSSs have been successfully operating at Nunhead Junction (Southern Zone) since October 30th 2000. The HPSSs have been installed at Points 989 (Facing) and 990 (Trailing), and on a typical day each point end is operated 100 times and has 150 trains passing over it.

In addition to the performance of the HPSS, the S&C at Nunhead was machine tamped approximately one month after installation and operational service. This is believed to be the first time that S&C has been maintained in this way in the UK railways and offers major benefits in terms of track availability.

Product Acceptance: Following successful completion of the Critical Review period the HPSS has received Product Acceptance from Railtrack (and subsequently Network Rail) for a range of applications including RT60 and Swing Nose Crossings. Further work is under way to increase this scope of approval, thus allowing the widespread introduction of HPSS into the UK rail infrastructure.

Development of the 'PowerLink' Backdrive

Initial HPSS installations utilised an earlier design of Torsion Backdrive, supplied by a third party. A number of problems were encountered during operational service that led to loss of system availability, primarily due to a lack of efficiency and an insufficient gear ratio within the backdrive assembly.

IAD Rail Systems therefore undertook a design and development programme in 2003, to develop their own Torsion Backdrive which is now marketed as the 'PowerLink' Backdrive.

In June 2003, two prototype 'PowerLink' backdrives were installed at Dorridge 672A & Bpts in Network Rail's Cross Country route. The resulting in-track trial demonstrated that the 'PowerLink' design was a highly reliable, high efficiency system, containing a number of improvements over previously available Torsion Backdrive systems.

The key design features of the 'PowerLink' Backdrive are as follows:

Articulated front and rear (and where applicable, mid) stretcher bars (drive assemblies), incorporating 'swinging' links that ensure lateral loads are efficiently applied to the switch rails, particularly at the rear of the switch.

Each articulated ('swinging') link uses 'sealed for life' bearings and fitted Drive Pins that ensure frictional and displacement losses are minimised and that maintenance requirements are eliminated.

The gear ratio at the rear drive assembly has been increased to ensure that sufficient force and displacement is applied at the heel of the switch (typically 1 : 1.34 for an RT60C switch).

Bearing Block assemblies utilise 'sealed for life' track roller bearings that offer good rolling contact with the outside diameter of the Torque Tube. This ensures that the displacement losses and frictional losses are minimised, thus maximising the efficiency of the 'PowerLink' Backdrive.

'PowerLink' Backdrives have now been fitted to a large number of RT60 switches (sizes C through to SG) throughout the UK rail network, and have proved to be extremely reliable in service. Recent installations include the new junctions at Ledburn, Tring and Bourne End (West Coast Route Modernisation) and the new Channel Tunnel Rail Link remodelling at St Pancras (shown left).

The High Performance Switch System (HPSS) is a high reliability, low maintenance, self-monitoring and fully tampable Switch Actuation System designed for widespread use, especially in critical high speed or high traffic density applications within Network Rail's Infrastructure.

Design Philosophy

The HPSS design philosophy has been driven by the need to exceed key operational performance parameters, whilst meeting all safety requirements. Solutions were developed by analysis of the fundamental function of the equipment whilst gaining an understanding of the failure modes of existing Switch and Crossing equipment such that they could be designed out of the new system.

The resultant design therefore offers:

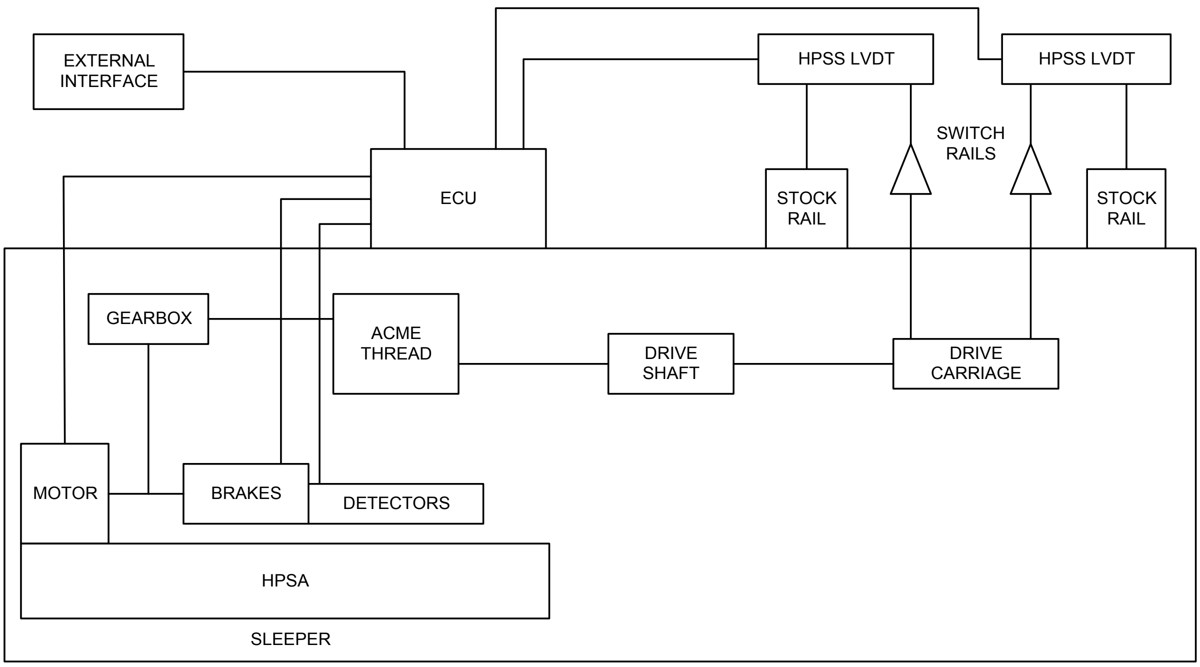
25 year service life
Zero scheduled maintenance
Ease of installation, commissioning, test and fault-finding
No requirements for “men on track” to adjust, replace, or maintain system performance
Tolerant of wear, operating environment, including extremes of climate
Flexible design of control system, allowing all future remote Condition Monitoring requirements to be accommodated.

Design Overview

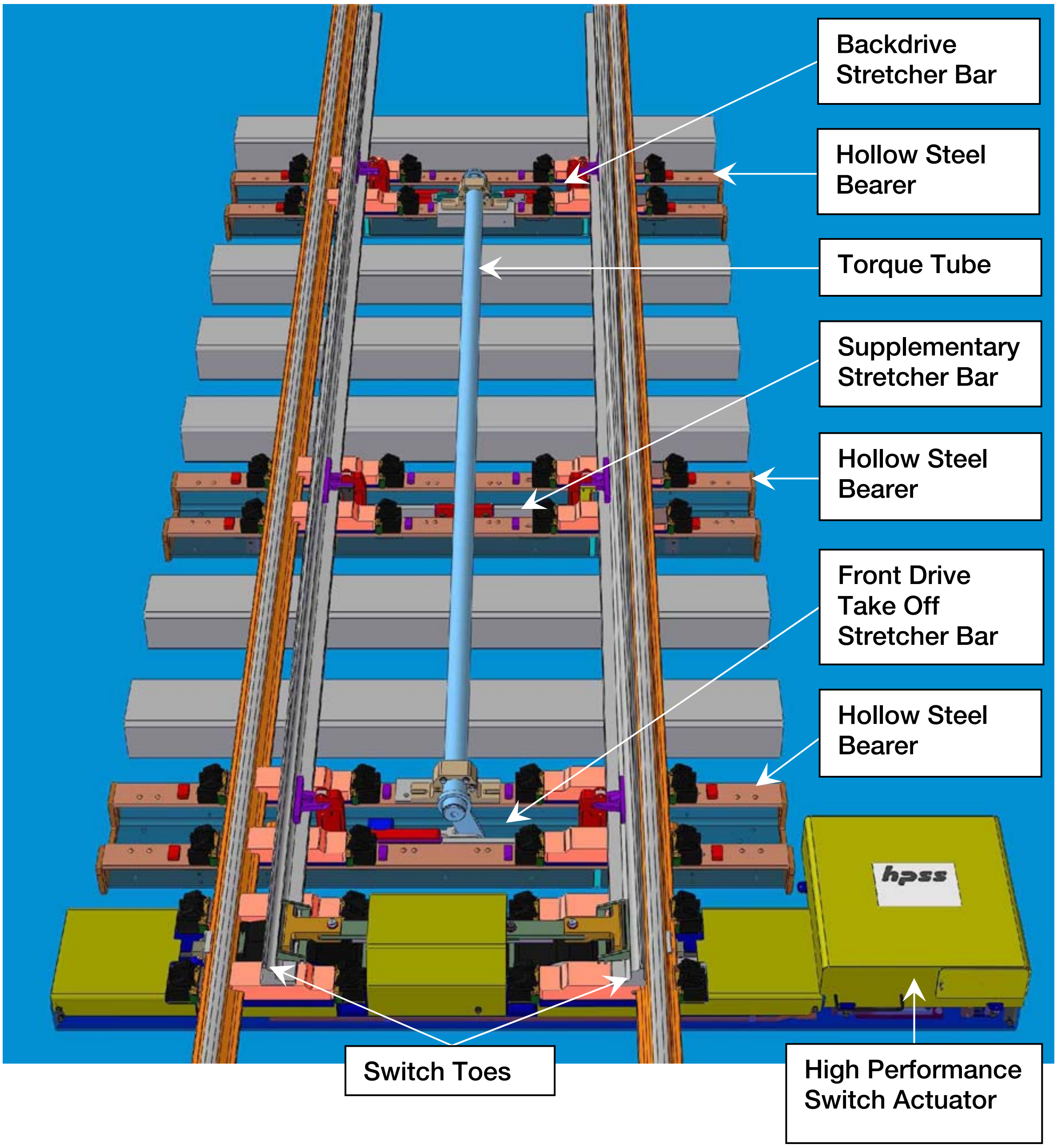
The HPSS (layout shown overleaf) comprises the following main sub-systems of a Switch & Crossing (S&C) System:

- In-Bearer High Performance Switch Actuator (HPSA)
- In-Bearer Supplementary Detection Sub-assemblies
- In-Bearer Torsion Backdrive Assembly

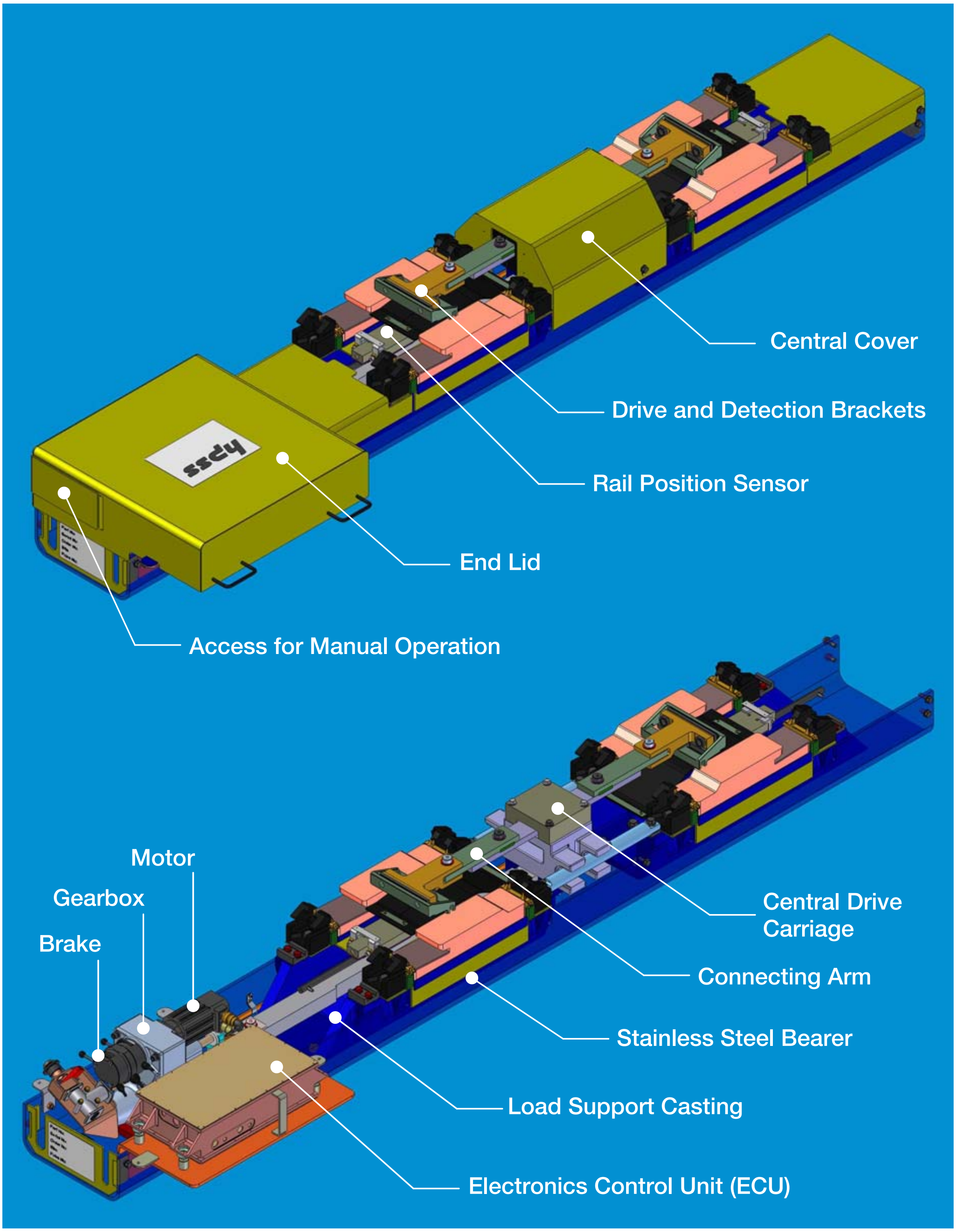
The following block diagram represents the HPSA:



HPSA Block Diagram



Layout of HPSS-based Switch Panel (HPSA plus 'PowerLink' Backdrive)



High Performance Switch Actuator (HPSA)

The system has been designed to integrate with all existing S&C Track components, ensuring that benefits can be accrued from full renewal projects though to “retrofits” where new HPSSs may be installed into existing trackwork.

Simplicity of system design, installation and commissioning, means that the HPSS may be installed in all sizes of S&C, from A (smallest size, lowest turnout speed) through to J (largest size, highest turnout speed). Further development work has been completed and HPSS applications are now available for RT60 turnouts (C through to SG), a large number of which are operational within Network Rail’s infrastructure including the West Coast Main Line.

High Performance Switch Actuator

The HPSA is an electromechanical unit that provides the Actuation, Locking and Detection functions for the S&C system. To provide a fully integrated solution all components are mounted in a high integrity Hollow Steel Bearer (U-Channel) which replaces the conventional concrete or timber bearer.

The Hollow Bearer assembly also provides Track Support over the HPSA, carried out by two Load Support Castings securely mounted within a Stainless Steel U-channel. These Castings, together with the Resilient Pads, Half Baseplates and Retaining Shoulders provide the Vossloh/Pandrol 'Fastclip'/ Schwihag style mountings for the appropriate Switch and Stock rails. The use of resilient pads within the HPSS design also ensures that rolling stock dynamics through the S&C is the same or as near to that for plain line, therefore passenger ride comfort is maintained.

Actuation of the Switch Rails is achieved using a d.c. Brushless Motor driving through a 2 stage Spur Gearbox with a final Leadscrew output stage. The Gearbox is mounted securely to the base of the Bearer with its output shaft connecting to a central Drive Carriage. The use of a d.c. brushless motor offers 2 key advantages, one is that the absence of brushes ensures the motor is a maintenance free unit, secondly the use of electronic commutation is a major safety feature in that the motor is a.c. and d.c. immune and cannot be spuriously operated.

The Drive Carriage ensures that the Gearbox assembly is not subjected to excessive side loading or vibration during the passage of trains. Both Switch Rails are driven by the Carriage via independent Connecting Arms, which have sealed for life Spherical Bearings to tolerate rail creep and vertical movement, both of which are well known current causes of points failure.

Locking of the Switch Rails is achieved using the Leadscrew, which is inherently non-backdriveable. Locking integrity is further assured by providing a Duplex Brake Assembly, mounted on the Gearbox, in line with the Motor.

The position of each Switch Rail relative to its associated fixed Stock Rail is monitored using a Linear Variable Differential Transformer (LVDT), being clamped directly to the foot of the Stock Rail at the Toe of the Switch. This provides an absolute position measurement of each Switch Rail relative to its adjacent Stock Rail in both the open and closed positions. To ensure absolute system safety the rail positions are cross-validated by the detection circuits i.e. the closed rail detector also confirms the position of the open rail and vice versa. This is a fundamental safety feature and in key installations that have Condition Monitoring set-ups, may be constantly monitored for any signs of system degradation.

The principle of operation of an LVDT is similar to a Transformer, where an electrically energised primary winding generates electrical output from the secondary coil(s). The axial movement of an iron core, located co-axially within the cylindrical coil housing, provides a linear variation between output signal and rail position.

LVDTs have no electrical contacts, and therefore do not suffer from wear, contamination or contact bounce due to vibration, which remains one of the most significant problems with existing Points Machines in service today.

LVDTs are also used to monitor supplementary rail positions in order to meet Network Rail's 12mm (CEN54) or 15mm (RT60) Obstruction Detection requirement defined in Company Standard "Requirements for Powered Point Operating Equipment" (RT/SRS/2001).

The entire HPSS is controlled and monitored by an Electronic Control Unit (ECU) that receives external demands, controls the actuation and locking sequence, provides detection output to the external signalling system, and contains the Condition Monitoring circuits and data storage. By designing the ECU as a number of discrete circuit boards contained within a fully waterproof, EMC compliant housing, the HPSS design is compatible with any signalling system and importantly offers the ability to be upgraded to contain additional circuitry for any new signalling system interfaces, or enhanced remote Condition Monitoring that is required in future.

Interfaces at the HPSA are via Plug Couplers which are used throughout the design. This is a major improvement over existing Points Machines and allows simplicity of installation and major reductions in test times in track, thus minimising possession times.

Torsion Backdrive

The HPSS utilises the 'PowerLink' Backdrive system that offers significant advantages over conventional backdrive systems currently in use in the UK rail network. Existing backdrives are complex to set up, and use bell-cranks and rods that require extensive adjustment. Conventional backdrives are also susceptible to going out of adjustment with changes of temperature through the seasons, thus requiring maintenance teams on track.

The 'PowerLink' Backdrive is a Torsional Backdrive that consists of a torsion tube, adjustable stretcher bar and a hollow steel bearer and is shown in the HPSA layout on Page 11.

The key features of this design arrangement are that the torsion tube is mounted in the four-foot (between the running rails), and the stretcher bars are mounted within the hollow steel bearers, therefore full machine tamping of the switch becomes possible. As discussed elsewhere in this document, failure to tamp S&C is one of the major causes of points failure in today's railway.

Operation of the 'PowerLink' Backdrive is initiated by the powered operation of the Switch Rails by the HPSA, the torsion tube transferring the switch toe drive to move the rear of the switches into position. Linear movement of the switch rails is transferred from the front to the back of the switch by the rotary motion of the torsion tube. The 'PowerLink' Backdrive has a gear ratio of approximately 1 : 1.34 (RT60C), to ensure that sufficient force and displacement are applied to the rear of the switch.

As the 'PowerLink' Backdrive is an integrated unit energy losses are reduced, and temperature changes effecting the length of the torsion tube do not have an effect upon the switch rail position. This eliminates the potential for the switch rails to be moved out of position when not commanded, and improves both system availability and safety.

The hollow steel bearers provide the same structural support as a normal bearer. The hollow recess within the bearer offers a housing for switch heaters, the backdrive linkages and stretcher bar, and Supplementary Detection assemblies where required. This design arrangement ensures that all items of equipment, plus interconnecting cables are safely housed and free from accidental damage, and also ensures that the ballast beds between the bearers are free from obstruction, thereby allowing full machine tamping of the switch.

Installation and Commissioning

The simplicity of the HPSS design, coupled with the use of a hand-held computer (the HPSA Handset), means that installation, commissioning, maintenance and fault-finding are straightforward operations requiring minimal time to complete.

The HPSA Handset is a pre-programmed hand-held computer that enables the ECU to obtain the necessary Switch Rail position data during HPSS Commissioning, such that detection reference datum positions are set within the ECU. The unit is plugged in to carry out HPSS Commissioning (ECU Datum Set-Up), and removed when commissioning is complete. It may also be used to carry out a Condition Monitoring data download, plus it has the ability to be used as a diagnostic tool in the event of an apparent fault.

The major improvement of HPSS over any other Point Machine is that once the system is installed there are no adjustments necessary in order for commissioning to be carried out. The points are operated under power from the external signalling system to both "Normal" and "Reverse" positions, at which time the HPSA Handset is used to acknowledge these positions, thus allowing the ECU to record them in non-volatile memory as reference datum positions. With this simple activity complete the system is commissioned and therefore ready for operation, subject to the mandatory Facing Point Lock (FPL) test being carried out. The HPSS Commissioning activity takes several minutes compared with the arduous commissioning process for existing Point Machines, which often require repeated adjustment and re-test in order to commission successfully.

HPSS Operating Sequence

Powered operation of the HPSS is achieved via standard relays in a Location Case or Relay Room. The HPSA is designed to integrate with a.c., d.c. or Solid State Signalling systems. Command and Detection cables are the 10 Core and 4 Core types commonly used for Point Machines.

On receipt of a valid command the ECU energises the duplex Brake to release the Switch Rails and then operates the motor until a stall condition is detected via the motor sensors, that is the closing Switch Rail has driven hard up against its mating Stock Rail.

When the Switch Rail has stalled out against the Stock Rail Motor power is removed and the Brake is de-energised, restoring both friction plates within the Brake to their holding position under spring power. The positions of the friction plates are monitored by two independent proximity sensors, which are located within the Brake assembly.

The ECU sets a valid detection output with the points in either the "Normal" or "Reverse" position when it has confirmed that all rail sensor positions are within their specified tolerances, that is the Switch Rails are in a safe and secure position, and that both Brake friction plates are in their holding position.

As a safety check an internal timer within the ECU removes power from the Motor if rail positions have not reached their specified tolerances within 6.5 seconds from receipt of a demand, and will not give a good output to the signalling system thus maintaining a "safe state".

Once the ECU has set a valid detection output, all rail sensor positions and Brake friction plate positions are continuously monitored to ensure that a valid detection output can remain.

The HPSS also has a facility for manual operation. This is achieved by manual rotation of the gearbox shaft via a standard Points Machine crank handle whilst manually releasing the brake. Manual operation may only be carried out after electrical power to the machine has been isolated via an in-built safety switch.

Built-In Test / Condition Monitoring

The ECU logic circuits include a number of “Built-In-Test” functions, which check that critical internal functions of the ECU and external performance of the HPSS are satisfactory. For example, these include bit parity checking to validate data, cross-verification of sensors positions and proving of ECU detection output relays.

The ECU also records and retains the performance of the HPSS for the last 512 operations. For example, recorded parameters include the actual positions of all sensors, time of operation, “Normal” or “Reverse” detection state and the total number of operations. All recorded data is obtained via the sensors that are integral to the HPSS design, rather than by external additions, therefore the system offers an extremely useful Condition Monitoring feature to the operator without a reduction in overall system reliability.

The HPSA Handset can be used for downloading the performance data from the ECU into a Laptop or Desktop PC. Communication between the ECU and Handset is via an RS232 link, however this interface design can be modified to communicate directly with a Remote Condition Monitoring system once the protocol for this has been defined.

The Handset also displays status information for the main components of the HPSS, this data can be used to assist in Fault-Finding to reduce unscheduled maintenance time, as shown below.

<u>**HPSA Handset**</u>

HPSS Maintenance

The HPSS is a “Zero Scheduled Maintenance” system, requiring only an annual inspection to confirm system integrity for continued safe operation. All internal components are designed to provide an operational life in excess of 25 years. The following paragraphs indicate how this has been achieved.

The Motor is a d.c. brushless unit and therefore does not suffer from brush wear or contamination. It has a high efficiency and power density and therefore well suited for a high duty cycle application. The internal ECU time limit and current limit circuits protect the motor from damage.

The Gearbox is a grease-packed unit, which is sealed for life and requires no additional greasing during its service life. This has been validated by Endurance Testing which demonstrated that after 360,000 operations the internal gearing still displayed its original machining marks with no visible signs of wear.

The ECU ensures that the Brake Friction Plates are only released and applied under static conditions and therefore no wear can occur.

The LVDTs used for rail position measurement, have no electrical contacts, and therefore do not suffer from wear, contamination or contact bounce due to vibration.

The Actuation and Detection Linkages have been designed to tolerate Switch Rail Creep and vertical movement without damage or the need for re-adjustment.

The ECU always attempts to drive the Switch Rail to a stalled position against the Stock Rail with a force of approximately 9kN. This ensures that, unless the system is genuinely obstructed, there will be no actual gap between the rails on the Closed side. This reduces the amount of load that is transmitted via the mechanism during the passage of trains since the Stock Rail supports the applied lateral loading. This feature becomes increasingly more important as train speeds increase to 140 mph.

The robust design of the Stretcher Bars provide additional stiffness and support to ensure that the open Switch Rail is securely held under vibration, thus reducing the transmitted loads into the actuation mechanism.

The method of commissioning eliminates the potential for incorrect installation with lock nuts potentially left loose. Any wear that takes place at the Switch and Stock Rail interface can be monitored via the recorded data. If the wear is within safe limits the system can be easily re-commissioned so that the ECU adopts the new reference positions of the rail.

Both the HPSA Point Machine and the ‘PowerLink’ Backdrive use ‘sealed for life’ bearings at key interfaces, thus reducing friction losses and eliminating the need for any lubrication.

The Facing Point Lock and Detection (FPL) test for HPSS is conducted under powered operation of the system. This means that the FPL test is truly non-intrusive, therefore there is no need for adjustments and no potential for Lock Nuts to be left loose.

Track Support Maintenance (Tamping)

Existing S&C systems are traditionally not tamped due to the amount of points machine drive and detection linkages in the four foot, and in particular the track bed between bearers. This can lead to degradation of the ballast (known as voiding) which in turn often leads to poor ride quality (passenger discomfort) and points failure (train delays).

The HPSS design layout permits full machine tamping to be carried out throughout the S&C, as there are no rods, linkages or cables located within the beds. This has been demonstrated at Nunhead Junction 990 Points, the entire tamping operation taking several minutes to complete, after which the points were tested and found to be fully operational and giving good detection.

Machine Tamping of HPSS (Nunhead Junction - November 2000)

Key Technical Advantages Over Existing Points Machines

The following features of the HPSA provide a system-wide technical advantage over other Points Machines currently in use in the UK railway infrastructure:

1. The main power input to the HPSA does not connect directly to a motor winding so it does not experience the same kind of onerous surge characteristic. Current inrush at machine power-up is electronically limited to a maximum of 6A for a period of 50ms. The current spike seen at motor energisation is in the order of 10 to 12A for approximately 50ms and again is electronically limited and so will not be exceeded. This may be beneficial in multiple point end applications when points are called simultaneously.

2. Normal running current is in the order of 4 to 6A at the nominal input supply of 120Vdc.

3. Output force of the motor is electronically limited so avoiding the risk of putting excessively high forces into the switch rail due, for example, to inappropriate setting of the clutch in an HW points machine.

4. Because the Electronic Control Unit (ECU) performs the power switching to the motor and the brake, the main points machine control relays do not have to break the electrical circuit when high currents are flowing, hence contact wear will be greatly reduced providing longer life and reliability. Currents at turn on are probably also much reduced compared with HW points machines so providing the same type of improvement.

5. Input current when the machine is stalled is controlled to approximately 8A as a function of the active current control at the motor. This is much lower than the typical 15A, which is the recognised stall current seen with a HW points machine with a properly adjusted clutch. Stress on the associated cabling and signalling is therefore reduced and is also consistent as it is not dependent on the set-up of the individual machines.

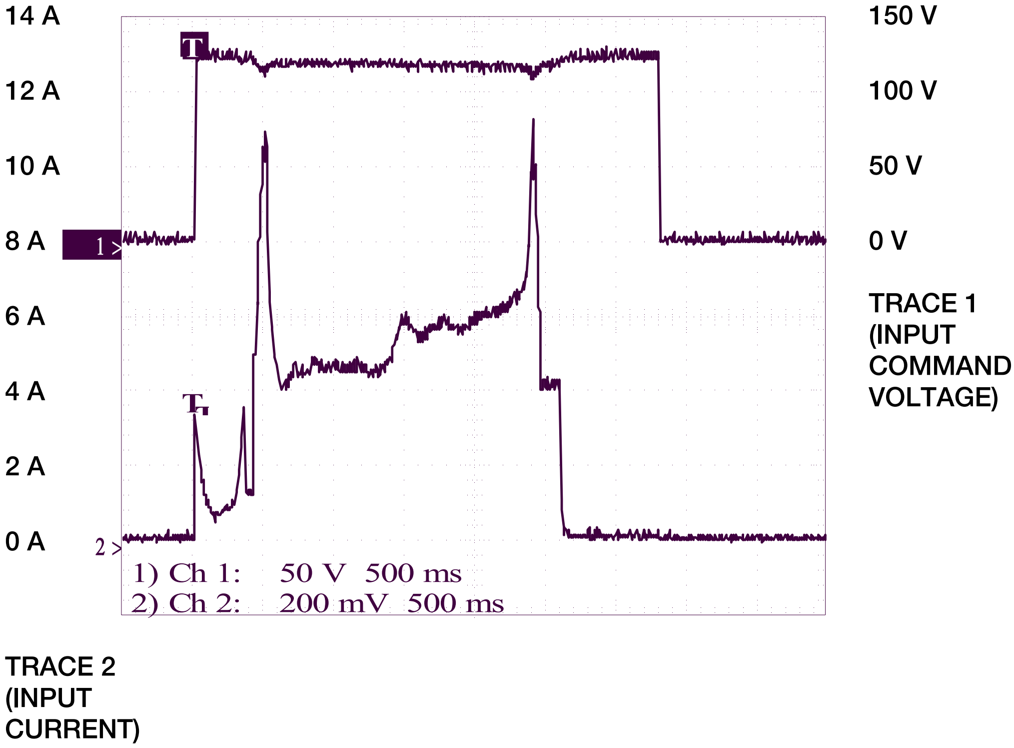
6. Reliability of the detection circuit is greatly enhanced because there are no microswitch assemblies along the track through which the detection signals pass. The electromagnetic safety relays through which the signals pass in the HPSS are located in the ECU which is a sealed robust enclosure utilises anti-vibration mounts to isolate it from potentially damaging vibration and shock. The switching relays within are therefore contained in a clean, dry and stable environment ensuring contacts remain in a good condition for the life of the equipment. Loop resistance will be low and consistent over time. Snubber networks have been incorporated in the ECU to ensure the relay contact wear is minimised regardless of the detection circuit format being used (ac, dc or SSI). This also means that retrospective fitting of SSI detection circuits to installations previously using ac or dc detection will not require that any detection equipment in the points system be replaced as a result of the usual relay contact burning.

7. Because the number of relay contacts in the detection circuit path within the ECU is the same regardless of the number of supplementary detectors, the reliability factor for this section will be the same regardless of the length of the turnout.

8. The ECU incorporates an internal timeout function to turn off the motor if it has not achieved correct position within 6.5 seconds of validating the command to move. This means the power-off timer relay can be designed out of the signalling so reducing cost and improving reliability.

9 The HPSA Handset used for diagnostics and machine set-up enables performance trends of any individual machine to be analysed in order to identify performance and specific 'out of correspondence' failures due to excessive gaps in a closed switch. This enables the location of problems in the track work simply by looking at the handset screen rather than by detailed inspection of the track by an experienced maintainer. Typical examples of identifiable failures are tie bar mal-adjustment in backdrives and broken slide pads. These kinds of faults are identified by locating the sensor that is causing detection to fail (seen as an excessive gap displayed in mm on the handset) and then checking the condition of the hardware around this detector's location. Should a sensor become disconnected this is also easily diagnosed using the handset rather than requiring the use of a DMM for instance and the laborious testing of multiple microswitches and cable looms.

10 Circuit and motor damage through excessive temperature is avoided by using thermal trips in both the motor and the drive electronics. If tripped during a movement, the actuator will complete the movement and then lock out any further commands until such time as the temperature drops back to within acceptable working limits.



11 The trace above shows a typical trace of the input command supply (120V battery) and the supply (input) current into the machine. The initial current spike is the current which charges up the capacitor bank in the motor controller section and is controlled to less than 6A. At the dip, the command is being validated by the logic. When validated, the brakes are energised (the second spike) which stabilises current to 1A. The next spike (up to 11A in this case) occurs when the motor is started. The normal running current of about 5A can then be seen which increases slightly to about 6A when the backdrive picks up. At the point when the switch closes and the motor stalls, the final current spike is seen. At this point, the motor is turned off and detection is established. The command is then removed. This trace will vary slightly in terms of absolute current values and timing depending on the supply voltage, backdrive set-up and general condition of the switch but will still resemble this typical profile.

Functional Specification

Designed to be compliant with Network Rail Specification:
"Requirements for Powered Points Operating Equipment" RT/SRS/2001 Issue 2 (Dec 2001)

Performance requirements:

- 25 in-service year life
- 350,000 cycles or 10 years (operational life of major components)

Designed for high speed railways

Allows automated tamping through the S&C system

Signalling Interfaces

Compatible with all signalling systems

Detection system compatible with AC/DC and Solid State Interlocking (SSI) signalling systems

Track Interfaces

Designed for use with:

- shallow depth rail (CEN54 & CEN60 rail section)
- switch sizes A to H
- full depth rail (113A)
- 3rd rail compatible
- swing-nose crossings

Physical Size/Weight

Length:	3.4metres
Width:	400mm
Depth:	Soffit level consistent with CEN54 and CEN60 rails
Weight:	700kg (approx.)

Complies with Network Rail Structure Gauge and Kinematic Envelope requirements (including 3rd rail)

Performance

Max Force:	8 to 9kN
Time of Operation:	less than 4 seconds for 120mm stroke

Installation/Commissioning

Time to install:	3 to 4 hours (retrofit)
Time to commission:	10 minutes (using hand-held pre-programmed computer)

Control System

Electronic Control Unit (ECU)
Solid state programmable electronics (no software)
Built-in Condition Monitoring (CM) for preventative maintenance
(Operating parameters recorded are switch operating elapsed time, switch rail position relative to stock rail)
Condition Monitoring data available via serial comms link from ECU

Drive

DC brushless motor
Electronic control of motor (Hall effect commutation) and brakes
2-stage reduction gearbox
Drive output via acme leadscrew

Locking

Non-backdriveable leadscrew plus duplex brakes
No adjustment required

Detection (Primary and Supplementary)

Continuous detection of switch rail position (open and closed rails, cross-checked)
Non-contact sensor technology, utilising Linear Variable Differential Transformers (LVDTs)
No adjustment required

Materials

Manufactured from corrosion resistant materials (additional protection where required)

Reliability/Availability/Maintainability/Safety (RAMS)

Failure rate: 3 to 4 times better than existing systems
(Based on Network Rail FRAME failure data)
Zero maintenance (annual inspection)
Maximum time to replace module: 30 minutes

Environmental

All electronics sealed to IP67 requirements (resistant to full immersion)
EMC testing carried out to existing industry recognised standards.
Test specification compiled using the outline requirements of prENV50121-4 (Railway Applications – EMC Part 4: Standard for the emission and immunity of the signalling and telecommunications apparatus) updated to reflect the railway EMC environment at that time.
Competent Body Certificate (TCF Certificate No. 04/0022) issued January 2004, by ERA Technology, as required by the EMC Directive 89/336/EMC (UK EMC Regulations SI 2372).
Operating temperature range: tested to -20 to +60 degrees C
Unit contains integral switch heaters