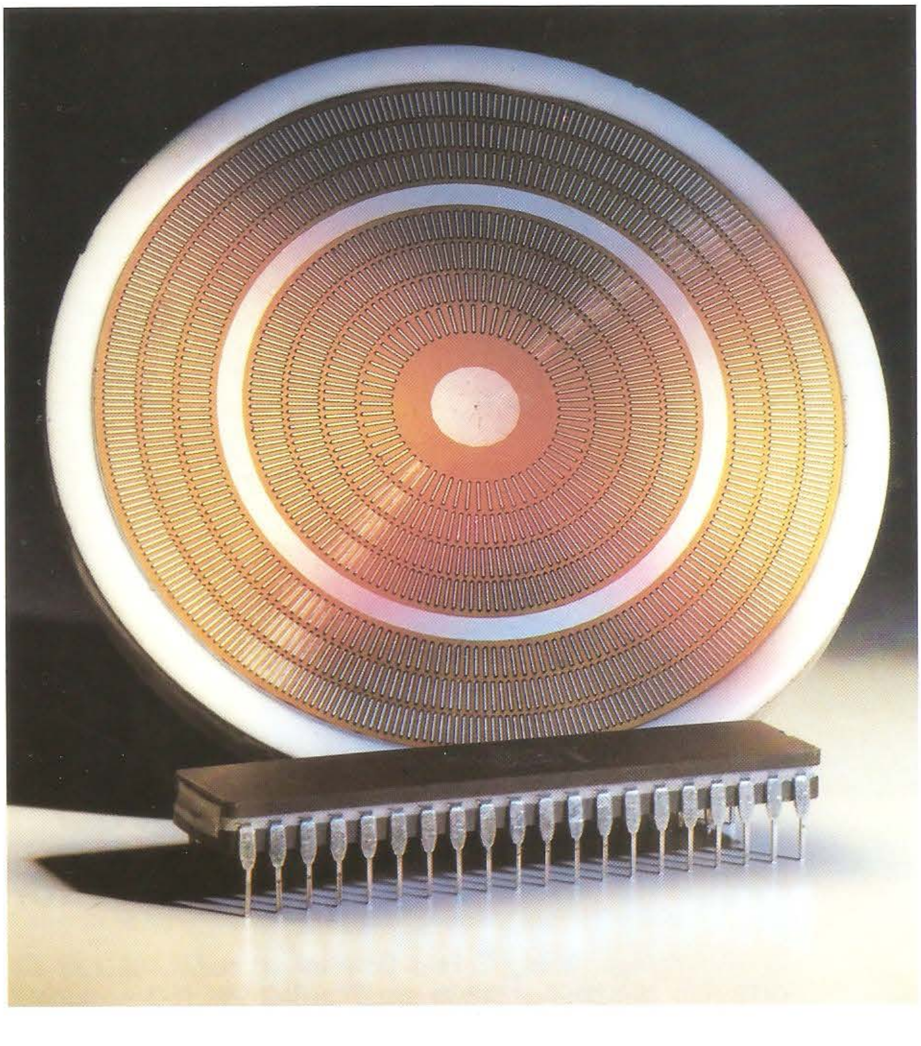
THAMES LINK

Dual voltage suburban multiple-unit trains with GTO/microprocessor control
Class 319

GEC TRACTION

GEC Transportation

A Thameslink train operating from the 25kV supply in the north London suburbs.



The intricate pattern of the GTO cathode is clearly seen in this view together with an 8086 microprocessor, now used as standard by GEC.

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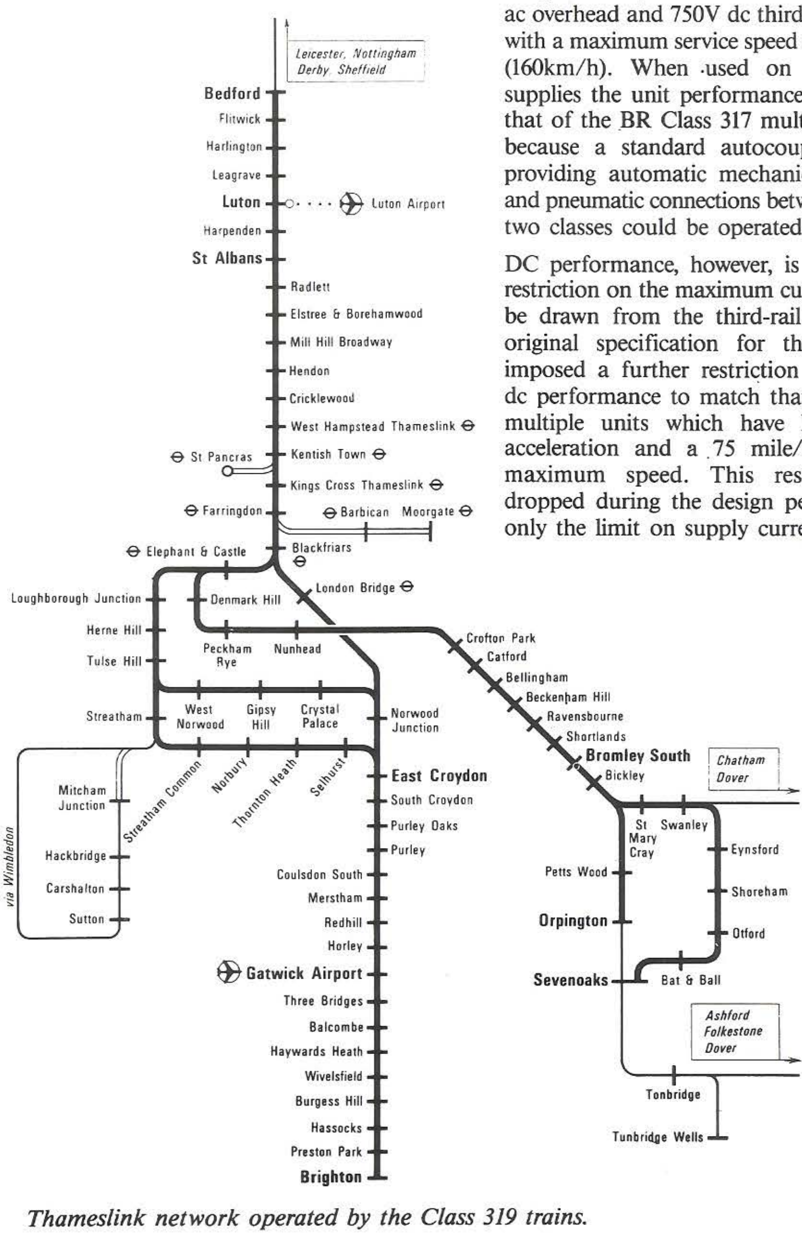
Dual voltage suburban multiple-unit trains with GTO/microprocessor control

The Class 319 electric multiple unit is one of the latest designs of rolling stock for fast suburban passenger transport in use by British Rail. These units work on routes crossing London through the Snow Hill tunnel between Farringdon and Blackfriars reopened in 1988. Services run between Bedford and Luton in the north, through Kings Cross, to Gatwick Airport, Brighton and other southern destinations.

The steel coach construction is based on previous BR multiple units but with modifications to the cab and front design which set the styling of the unit apart from earlier stock.

Each multiple unit train set consists of driving trailer 'A', motor coach, trailer coach and driving trailer 'B'. The motor coach carries all the propulsion equipment including the main transformer, rectifier and pantograph with a motor-alternator set and the air compressor mounted on the trailer coach.



Thameslink network operated by the Class 319 trains.

The Class 319 multiple unit trains are designed to operate from both 25kV, 50Hz ac overhead and 750V dc third-rail supplies, with a maximum service speed of 100 mile/h (160km/h). When used on ac overhead supplies the unit performance is similar to that of the BR Class 317 multiple unit and because a standard autocoupler is used, providing automatic mechanical, electrical and pneumatic connections between units, the two classes could be operated together.

DC performance, however, is limited by a restriction on the maximum current that can be drawn from the third-rail supply. The original specification for the equipment imposed a further restriction by requiring dc performance to match that of other dc multiple units which have lower overall acceleration and a 75 mile/h (120km/h) maximum speed. This restriction was dropped during the design period, leaving only the limit on supply current.

Three options were considered for the propulsion equipment:

Rectifier plus camshaft control
This scheme had been used by GEC previously on the Class 313 multiple units. Factors against this option were that the performance on dc-supplied routes would have exceeded that initially required as the traction motor characteristics were fixed by the ac duty specified. This scheme would also suffer from the number of wearing parts in the equipment which would require regular maintenance.

Thyristor-controlled bridge plus camshaft control
This system would have used the controlled bridge on ac and the camshaft on dc thus reducing maintenance somewhat. The disadvantage of this system was the amount of equipment to be fitted into the space on the motor coach underframe.

Chopper control
Using chopper control had the advantage of reducing the power consumption on dc compared with the camshaft options because the performance could be easily restricted to that specified. The energy saving was typically 20%-25% over the routes considered.

The use of moving and wearing parts was also reduced to a minimum, saving maintenance and also increasing reliability. Those contactors remaining in use would normally operate off-load thus minimising contact wear.

Chopper control also gave considerable improvement in power factor and psophometric current during initial acceleration when on ac compared to the thyristor-controlled bridge option.

This option was the most expensive of the three in capital cost but gave the lowest life cycle cost.

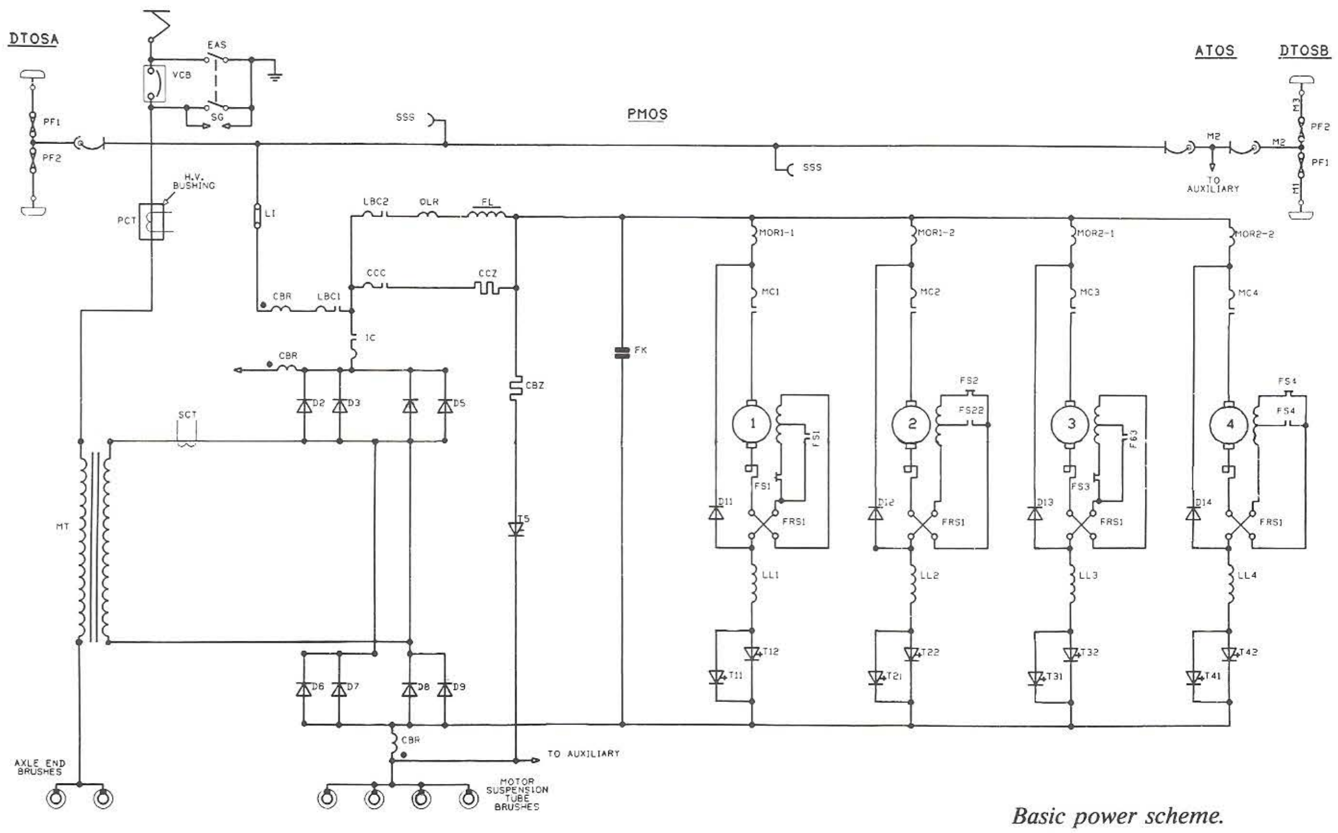
Propulsion

The propulsion equipment uses chopper control to regulate the current in four axle-hung, self-ventilated dc series-field traction motors, with a total continuous power rating of 1100kW, and a peak rating of 2000kW. Power is drawn from either the 25kV, 50Hz ac overhead conductor by the pantograph or from the 750V dc conductor rail by shoegear at the cab end of each driving trailer. The shoegear is connected to the motor coach and trailer coach by power cables and plug and socket jumper equipment.

Selection of the power supply to be used is made from the drivers' cab controls. DC power is drawn through the contactors LBC1 and LBC2 to the line filter circuit then to the four parallel motor circuits. AC power is taken through the vacuum circuit breaker VCB to the primary of the main transformer MT. The reduced voltage from the secondary of the transformer is then rectified by the diode bridge formed by diodes D2-D9.

The rectifier output is connected to the propulsion equipment by contactor IC and is also taken via fuses and plug and socket jumper equipment to the trailer coach for supplying the auxiliary equipment.

The line filter components prevent high frequency current ripple from the motor circuits being transmitted back to the power supply system. They comprise an iron cored inductor FL and a capacitor FK. The natural resonant frequency and impedance to 50Hz signals are the main electrical design constraints of the filter circuit.



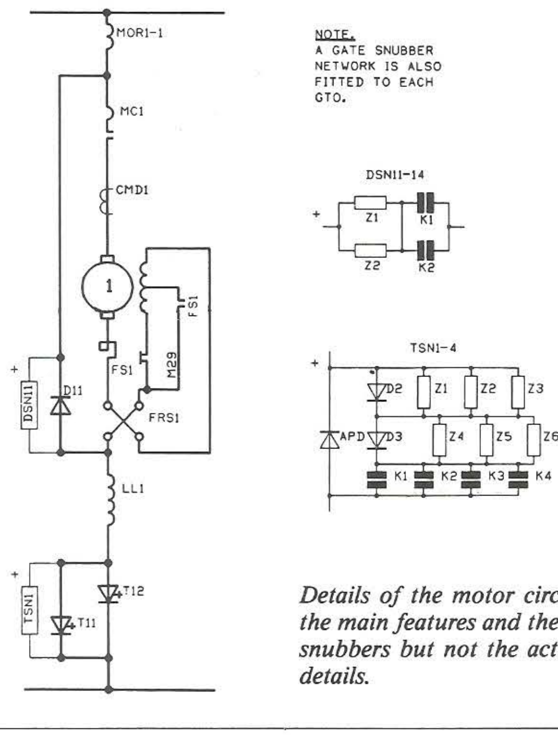
Basic power scheme.

Motor Circuits

The four motor circuits are identical in operation, connected in parallel across the line filter capacitor by contactors MC1-MC4, which permit isolation of motor circuits if necessary. Each motor circuit uses fixed frequency chopper control to give the required operating characteristics.

The motor circuit is similar to those used by GEC Traction on other dc multiple unit chopper equipment but whereas previous equipment has employed inductive/capacitive commutation circuits controlled by auxiliary thyristors, the Class 319 equipment uses high power Gate Turn-Off thyristors (GTOs) to directly conduct and inhibit motor current.

The use of GTOs reduces both the volume and weight of the propulsion equipment in comparison with L/C commutated choppers due to the absence of the high-power-rated commutation components. An L/C commutated chopper for this four parallel motor scheme would be 12% greater in volume and 29% greater in weight than the GTO equipment actually supplied.



Details of the motor circuit showing the main features and the presence of snubbers but not the actual snubber details.

GTO devices have only recently become commercially available at the necessary current and voltage ratings due to advances in thyristor design and manufacturing processes. The Class 319 equipment is the largest application of GTOs to a British rolling stock fleet to date, and represents a considerable increase in the technology applied to British Rail multiple unit propulsion.

The diode and GTO assemblies are all cooled by the natural airflow produced by movement of the vehicle. For this reason each motor circuit employs two GTOs connected in parallel, the devices being fired alternately to share the duty. This avoids any requirement to match device characteristics to prevent uneven current sharing which would occur if simultaneous operation were employed.

Diode D1 provides a path for motor current during intervals when neither GTO is conducting. The power dissipation of the diode is less than a GTO, so only one device is necessary in the circuit.

The GTOs are fired to give a motor current ripple of 300Hz, with the firing signals interlaced between one motor and another to produce a 600Hz current ripple from the common line filter circuit. By using the motor contactors, either bogie pair of traction motors can be cut out by the control equipment without affecting the supply current ripple frequency.

Direction control is by field reversal and the motors have a single field tapping to give an 80% weak field setting.

Auxiliary Supplies

The unit has a motor-alternator (MA) set to provide a battery charging supply at 110V dc and power various 240V ac, 50Hz single-phase loads. A single motor-driven compressor is fitted to provide compressed air for the braking system and electro-pneumatic control equipment. Both are mounted on the trailer coach underframe.

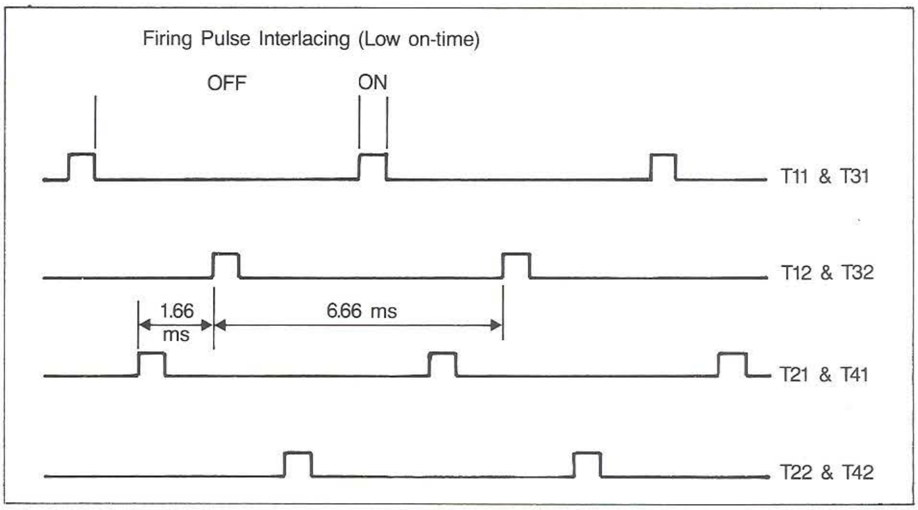
When the unit is operating from the 750V dc conductor rail supply, the MA set, compressor and heating equipment obtain their power from the connection between collector shoegear where it passes through the trailer coach, via isolating contactors and fusegear.

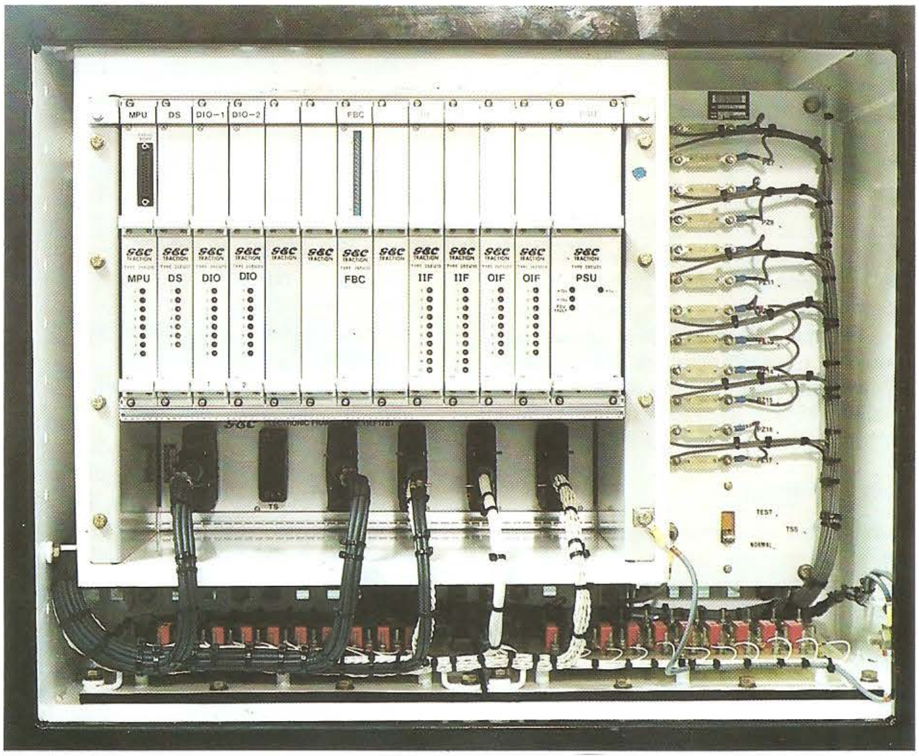
Power for this equipment is drawn from the main transformer and bridge rectifier when the unit is operating from the 25kV ac overhead supply.

Microprocessor Control

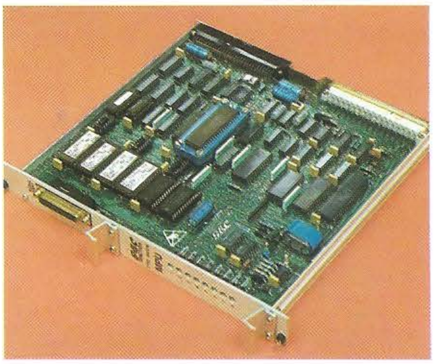
The propulsion equipment is under the control of microprocessor based electronics, allowing performance to be tailored closely to requirements and permitting recording and analysis of fault conditions to aid maintenance.

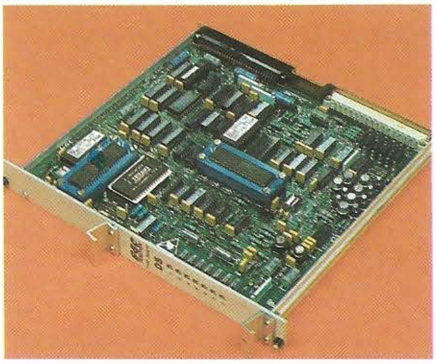
The control electronics contains three microprocessors — one for overall system control and two for timing and firing pulse generation to the GTOs. Each microprocessor continuously checks the integrity of operation of the others and ensures safe control should software or hardware faults occur. The control is fully digital (without analogue control loops) which gives high reliability and immunity to drift.





The electronics cubicle (above) and details of two of the printed circuit boards. The MPU (main processor unit) module is on the left.





Train lines and other 110V dc control signals are first filtered and then passed into the electronics via opto-coupled receivers to give 15V signals. Relays and contactors driven at 110V dc from the control electronics are interfaced by reed relays driven at 15V. Each reed relay contact is connected to a filter circuit. This arrangement ensures that voltage transients from the 110V train circuits are not transmitted to the control electronics.

Firing pulses for the GTOs are generated at 15V by transistor circuits in the control electronics and then passed to the GTO firing units via high noise immunity fibre-optic links. This separates the control electronics from noise sources in the power circuit.

To increase noise immunity a second level of signal isolation is provided between the interface modules at 15V and the microprocessor system modules at 5V.

The control electronics are constructed in modular form in double Eurocard units. The modules are of standardised design to efficiently implement the various functions required.

The main processor unit (MPU) module contains the system control microprocessor, a 16 bit Intel 8086 device, together with all the associated memory devices and control logic. The control program is stored in Erasable Programmable Read Only Memory (EPROM) devices and temporary data is stored in static Random Access Memory (RAM).

This module carries a small battery to supply power to the RAM so that data is not lost when the external power is switched off. A programmable RS232 serial communications port is also fitted which allows a hand-held terminal to be connected to the system for test purposes, through a socket mounted on the front of the module.

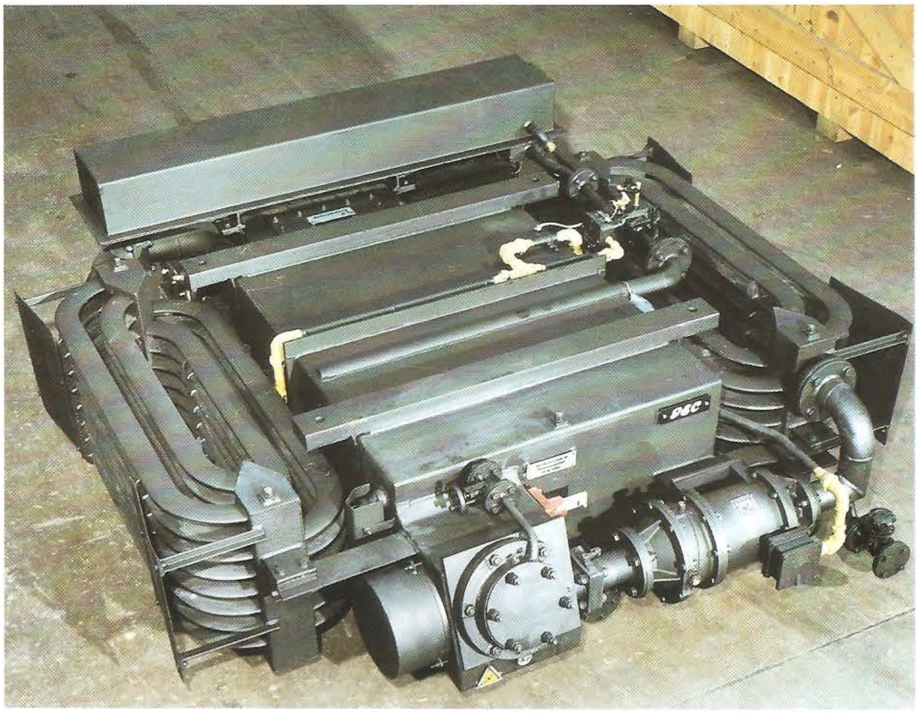
The digital servo (DS) module carries out the pulse control and timing operations for the chopper circuits. This module contains two Intel 8031 microprocessor devices, and associated interface components, whilst a crystal oscillator provides accurate high stability pulse generation.

The servo microprocessor continuously carries out the servo control function from digitised values of armature currents and line voltage to produce the required chopper on-time. This value is then passed to the pulse generation microprocessor which produces the required chopper frequency reference signal at 300Hz and turns the relevant GTOs "on" and "off" to the specified on-time.

Fault Monitoring

When the control electronics are switched on, each microprocessor carries out a self-test program to check all memory and peripheral devices are functioning. This includes checking that the control program stored in EPROM and the battery-backed RAM contents have not been corrupted. Once this testing is complete the main control program is then started.

The control program includes fault detection, correction and logging facilities for the operation of the control equipment outside the control electronics. This covers:—



Main transformer.

contactor operation,
line voltage out of range,
motor overcurrent,
feedback signal and train line signal integrity,
equipment overtemperature and,
GTO firing faults.

Individual fault conditions are indicated by illumination of red light-emitting diodes on the front of the electronics frame. The state of these fault lights is stored in battery-backed RAM so that the information is not lost when the electronics are switched off, allowing rapid maintenance analysis and repair of faults.

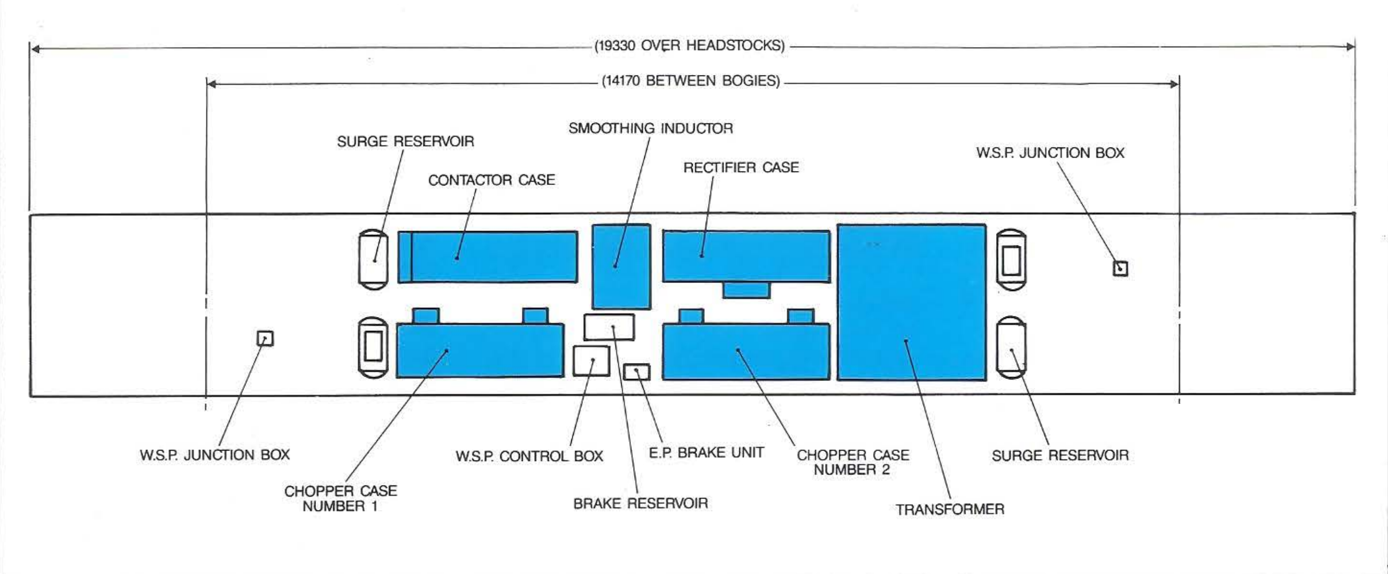
For certain faults the power circuit conditions before, during and after the fault can also be stored in the battery-backed RAM to give additional information for maintenance work. Access to these records is by use of a hand-held microcomputer terminal selected for durability in the service environment. The terminal can also be used to monitor power circuit conditions during operation of the propulsion equipment.

Arrangement of Equipment

The main transformer is mounted next to the bogie at the #1 end of the coach, with the pantograph and vacuum circuit breaker on the roof above. The rectifier case, line filter inductor and contactor case fill the remaining space along one side of the underframe, with the #1 and #2 chopper cases mounted along the other side.

The equipment cases are all designed to the same basic dimensions with a length of 2.4m with additional details mounted on the case structure as required. The cases are fabricated from high-tensile sheet steel and have removable front and rear covers to allow easy inspection of the equipment.

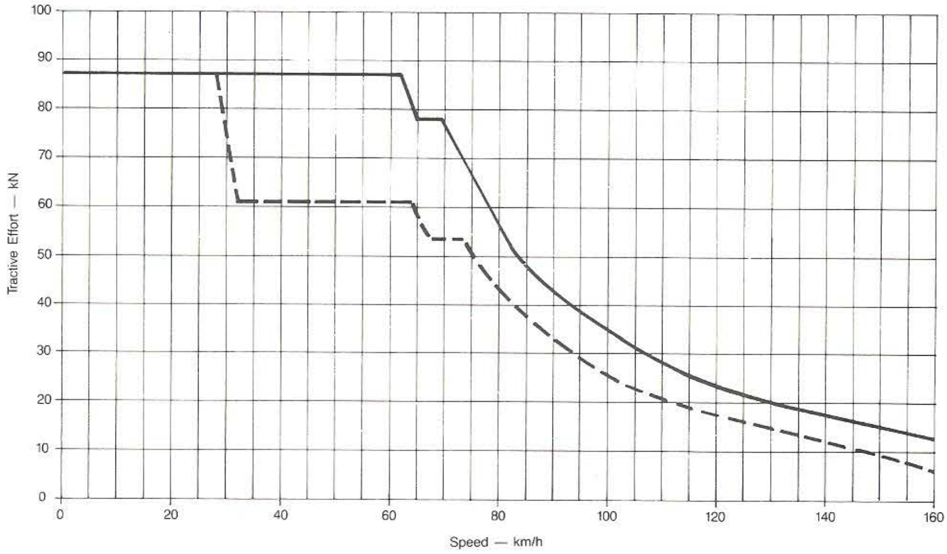
The line filter inductor is iron-cored to minimise flux leakage and, like the rest of the propulsion equipment, is naturally ventilated.



Layout of equipment on the underframe of the motor coach.

Data

Track gauge	1435mm	Max speed	160km/h
Minimum radius	70m	Total weight	144.2t
Body width	2816mm	Roof height	3774mm
Car length	19330mm	Floor height	1164mm
Unit length coupled	80720mm		
Traction supply	25kV AC; 750v DC		
Traction equipment	4×GEC traction motors of 268kW, with microprocessor and GTO controls		
Seating	316 high back seats in 3+2 layout		
Standing room	Capacity for 475 standing passengers		
Toilets	2 per unit		
Heating system	Electric heating		
Wheel diameter	925mm powered, 850 trailer		
Suspension type	Coil/rubber primary, air secondary		
Brakes	Electro-pneumatic disc		



The performance of the trains supplied from the 25kV overhead line is shown solid whilst the reduced performance on the dc network is shown dotted.

Change-over from 25kV ac to 750V dc (and vice versa) takes place at Farringdon station.

In service on the ac network (above) and on the dc (Southern Region) below.

GEC Transportation Projects Limited

Holding Company — The General Electric Company p.l.c. of England

P.O. Box 134, Manchester M60 1AH England
Telephone: 061 872 2431 Telex: 665451 Fax: 061 848 8710

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