Russian Voltage Regulators (Реле-регулятор напряжения)

Part XXVIII-1: PP-1/-30/-31/-31A for the Г-11/-11A Generator

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6-Volt Electro-Magnetic (Relay-Type) Regulator (PP-1/-30/-31/-31A) for the Г-11/-11A 7-Amp Alternator

• Background
  – Voltage Regulators Paired with Specific Generators/Alternators
  – Time-Line for Generators/Alternators/Regulators
  – Specs for Compatible 6-Volt Г-11/-11A Generator
  – Generator Application in Ural (M-72, -72M)/ Dnepr (M-72, -72N, K-750, -750M, Late MT-9, MT-10) Wiring

• What Are the PP-1/-30/-31/-31A Regulators?
  – External Voltage Regulator for Г-11/-11A Generator (7-Amp/45-Watt)
  – Electro-Magnetic (Relay-Type) Design
  – Years of Regulator Application: 1941 -to- 1963
  – First 6-Volt Russian Motorcycle Regulators
  – Later Superceded by PP-302 Regulator in 1963

• How Does It Work?
  – Regulates Generator Output Voltage to 6-Volts
  – Supplies Exciter Current to Vary Stator Magnetic Field
  – Provides Constant Voltage Regardless of Rotor Speed and Load

• Circuit Description and Operation

• Replacement
  – Replace PP-1 with PP-30/ -31/ -31A, Available over Internet

The Relay-Regulator (PP-1, a.k.a RR-1) was the first 6-Volt regulator used on Russian sidecar motorcycles.
## Types of Generators/Alternators for Ural (Урал) and Днепр (Днепр)

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**Notes:**
1. **Nomenclature:** The Cyrillic letter “Г” transliterates (Russian-to-Latin) to “G” or “L” or “T.” Thus we see Г-414 or G-414 or L-414 or T-414, all for the same part.
2. Cannot use Alternator with discharged battery or without battery.
Г-11 and Г-11А (G-11 & G-11A) 6-Volt Generator (1941-1957)

- 6-Volt / 7-Ampere / 45-Watt Generator
- Positive-Ground Casing
- Used on:
  - Ural (IMZ): M-72, M-72M, M-61
  - Днепр (KMZ): M-72, M-72N, early K-750
- Used in Conjunction with PP-1, PP-30, PP-31 and PP-31A Regulators

The Г-11 (G-11) generator served as a reliable source for 6-Volts for over 1-1/2 decades.
Alternators have progressed in output voltage and power, from the Г-11 (G-11) generator of 6-Volts/45-Watts in 1941, the Г-11А in 1952, the Г-414 of 6-Volts/65-Watt in 1957, the Г-424 of 12-Volts/150-Watts in 1974, the 14.3771 of 12-Volts/500-Watts in 1998.5, to the present-day Nippon-Denso alternator of 12-Volts/770-Watts.
Ural (Урал) М-72 with PP-1 Regulator (1941-1949)

1. Generator: Г-11
2. Regulator
3. Battery
4. Distributor
5. Breaker Points
6. Ignition Coil
7. Spark Plugs
8. Horn
9. Headlight
10. Lamp
11. Parking Light
12. Tail-Light
13. Sidecar Tail-light
14. Front Sidecar Light
15. Indicator Light
16. Central Switch
17. Ignition Key
18. Indicator
19. Dimmer Switch (Г-11А, 1950+)
20. Light Switch: Hi/Lo
21. Horn Button
22. Spark Advance

Generator (Г-11)

Regulator (PP-1)

Ural (Урал) М-72 with PP-31 Regulator (post-1949)

Generator (Г-11A, 1950+)

Regulator (PP-31)
Voltage Regulator PP-1 on M-72 Motorcycle

Wiring Diagram of M-72 Motorcycle with PP-1:
1 - main lamp Л1 - bulb of long and passing lights Л2 - parking lamp
2 - long and low beam switch
3 - central switch
4 - ignition switch
5 - light
6 - fuse
7 - sidecar lights
8 - horn
9 - generator
10 - battery
11 - voltage regulator
12 - rear lamp
13 - ignition coil
4 - breaker points
15 - distributor
16 - spark plug
PO - reverse circuit breaker
PH - voltage regulator
17 - horn button
18 - ignition advance handle
19 - switch lever for Hi/Lo beam

Note: Positive Ground on Early M-72s
Russian generators differ from alternators in that the magnetic (exciter) field is stationary and the generator windings are rotated. The output at the commutator is DC.
The PP-1 automatic voltage regulator consists of two relays; the reverse-current switch and the voltage regulator.
**Electro-Magnetic (Relay) Device**
- Periodically Switches Additional Resistance into Generator Exciter Winding

**Consists of Two Relays:**
- **Voltage Regulator (PH)**
  - Automatic Voltage Control as Number of Revolutions and/or Load Current Changes
  - Voltage Regulator Decreases Output Voltage as Load Current Increases
- **Reverse-Relay (POT)**
  - Switches Battery In-and-Out
  - Automatic Connect/Disconnect of Generator

**Factory-Set, Lead-Sealed Housing**

The Г-11 generator puts out 6.5-Volts at 1,500 rpm and 8.5-Volts at 5,000 rpm (no load). At full-load (7-Amps) the generator produces 6.5-Volts at 2,500 rpm and remains at 7-Volts up to 6,000 rpm. The PP-1 relay-regulator keeps the output voltage between 6.5 and 7.0-Volts.
The PP-1 is distinguished from the PP-30/-31 series of regulators in that it has a taller cap with hold-down nuts.
Relay-Regulator PP-1 (Реле-регулятор напряжения PP-1)

PP-1 Regulator
List Price: 378 rubles
(motofan.in.ua)
PP-1 Description

- Consists of Two Relays:
  - Reverse-Relay (POT)
    - Electro-magnet core (4), Yoke (13), Armature (3) with Tension Spring (12), and Contacts 1&2
  - Two Windings: Shunt (ШО) and Series Current (CO)
  - Two-Step Voltage Regulator (PH)
    - Electro-magnet core (7), Armature (6) with Return Spring (8) Two Fixed & One Two-Sided Movable Contacts (5), Series Resistors (9 & 10)
    - Three Windings: Shunt (ШО), Compensatory (КО) and Series Current (CO)

Reverse-Relay (POT)

Shunt (ШО) Winding

Series Current (CO) Winding

Generator (11): Г-11

Two-Step Voltage Regulator (PH)

Resistor (9): 1.2 Ω

Resistor (10): 4.4 Ω

Compensatory (КО) Winding

Series Current (CO) Winding

Exciter Winding (11)

Rotor Generator Winding

Armature-Core Gap: 0.6-0.8 mm

Contact Gap: 0.25-0.35 mm

Armature-Core Gap: 0.9-1.1 mm

Contact Gap: 0.25-0.30 mm

Exciter Winding (11)
PP-1 Operation

- **Ignition On / Engine Off or Idle (Generator Rotor Not Rotating or Low rpm’s)**
  - Reverse-Relay (POT) Pins 1 & 2: Open
  - Two-Way Regulator Relay Contact (5) Pulled by Tension Spring (8) to Upper Fixed-Contact Connected to Case
  - Generator Exciter Winding (11) Connected to Body thru Compensation Winding (KO) and Movable Contact (5)
- **With Increasing Generator Speed**
  - Armature Current Passing thru Series Winding CO Magnetizes Electromagnet Core
  - Attracts Armature (3), Connecting Reverse-Relay Contact (2) with Contact (1)
  - Current Charges Battery and Supplies Ignition/Lighting Circuit
  - Under Influence of Increasing Voltage Attracts Armature (6), and Two-Way Regulator Contact (5) in Middle Position
  - At Same Time, Two Series Resistors (R9 & R10) Inserted in Series with Generator Exciter Winding (11) and Compensation Winding (KO)
- **With Further Increase of Rotation Frequency of Generator**
  - Additional Resistance Prevents Increase of Generator Voltage in Excess of Specified Limit
  - Regulator Armature (6) Attracted to Electromagnet and Movable Contact (5) Pulled against Lower Contact, Closing Short-Circuited Generator Excitation Winding
  - Generator Voltage Decreases and Armature Returns to Middle Position, and Again to Closed Position with Upper Contact
  - Two-Step Voltage Regulator (PH) Armature, Vibrating, Supports Voltage Generator within 6.5 -to- 7-Volts
Regulator PP-1 Operation: Reverse Relay (POT)

- The reverse circuit breaker is used to automatically disconnect the generator from the battery when its voltage is lower than the battery voltage.
- When the engine is running at a low crankshaft speed (below 1,250 rpm), the generator voltage (7) is lower than the battery voltage (9). The current flow direction is determined from the positive pole of the current source to the negative. In the interior of the source the current flows from the negative pole towards the positive. From the positive pole of the battery, in this case the source of the current, the current flows through the mass to the receivers as well as to the control lamp (10) via the generator windings. The light (10) illuminates when the ignition is switched on and goes out when the reverse circuit breaker contacts are closed, i.e. when the battery is started charging.
- Since the generator voltage is low, the current in the circuit winding is also small, and the magnetic flux generated in the core (1) is not sufficient to overcome the force of the spring (6), contacts (3) remain open.
- As soon as the crankshaft speed exceeds 1,250 rpm and the generator voltage reaches 6.5 to 7.2 V, the current in the thin core shunt (4) will increase, the magnetic force will overcome the spring force (6) and the armature (5) will be pulled through the core by closing contacts (3). The current from the generator's brushes will start flowing to the receivers and to charge the battery. The battery converts in this situation from the current source into the receiver, and the direction of current flow reverses.
Regulator PP-1 Operation: Reverse Relay (POT) (cont.)

• The main current flows from the generator’s plus brush to the ground, and from there to the paralleled receivers and to the battery. Next, the negative current flows to the fixed contact of the circuit breaker and through the closed contacts (3), armature (5), yoke (8), thick winding (2), and generator clamp, to the negative brush. The low resistance of the coil of the circuit breaker causes the potential difference between the negative pole of the battery and the generator's brush to be very low, thus stopping the current from flowing through the control light (10).

• To the thin winding of the circuit breaker, the current flows from the ground, then passes through the thick winding, continuing the same way as the main current, returning to the generator. The direction of current flow in the thin and coil windings is the same, and the coils produced by the windings add up.

• By reducing the number of turns, and thus the voltage of the generator, to the extent that the battery voltage exceeds the generator voltage, the current from the battery starts flowing through the windings of the circuit breaker in the opposite direction. In this way, it demagnetizes the core and the spring opens the contacts, opening the main power circuit and protecting the battery from being discharged by the generator. The purpose of the coil winding is to amplify the magnetization of the fine winding by increasing the number of turns and vice versa - accelerating the degaussing of the core at lowering rotational speed.

Reverse Relay
1. POT core
2. Thick winding
3. Relay contacts
4. Thin core shunt
5. Armature
6. Spring
7. Generator (Г-11)
8. Yoke
9. Battery
10. Dashboard light

Note: Positive Ground!
• For the generator's excitation winding, current is supplied via a voltage regulator. Its purpose is to maintain a constant voltage of the generator at variations in its speed. To achieve constant voltage, it is necessary to reduce the magnetic flux of the poles together with the acceleration of the generator speed. For this purpose, reduce the current in the excitation winding by adding additional resistance to the circuit. This is what the voltage regulator deals with. It consists of a yoke (1), iron core (2) with a thin and thick winding, contacts (4), one of which is located on an armature, and a pulling spring (3). The spring keeps the contacts closed, pulling the jumper up. The core of the windings, forming an electromagnet, attracts the jumper downwards, trying to open the contacts.

• The current flows from the mass after the thin winding of the core, magnetizes it and returns to the generator clamp. However, this magnetization is not sufficient to overcome the force of spring (3) unless the crankshaft rotational speed exceeds 1,900 rpm. The current of the excitation winding passes through a small resistance, i.e. from the ground through the support (5), fixed contact of the voltage regulator (PH), closed contacts, armature, yoke (1), regulator terminal, conductor, generator clamp, excitation winding and negative brush generator.

Diagram of operation of RR-1 voltage regulator. Generator voltage lower than battery voltage. Reverse circuit breaker contacts (POT) open.

1. Yoke
2. Iron core
3. Spring
4. Contacts
5. Support
6. Resistor

Note: Positive Ground!
Regulator PP-1 Operation: Voltage Regulator (PH) (cont.)

- As the crankshaft rotational speed increases, the generator voltage increases until the limit value is exceeded, which causes the voltage regulator to run. As the generator voltage increases, the current in the thin winding of the regulator increases, so the magnetic flux of the core increases. When the magnetic force strikes the force of the spring (3), the pins (4) will open. Then the current to the excitation winding will flow through the additional resistance (6), connected in parallel to the contacts. As a result, the total resistance of the circuit will increase significantly, the excitation current will decrease, causing the generator's magnetic flux to decrease and, consequently, the voltage drop of the generator. When the generator voltage drops, the current in the windings of the voltage regulator is reduced, the spring closes the contacts and the current to the excitation winding starts to flow without the additional resistance. The generator voltage is again increasing and the whole process is repeated. The voltage regulator contacts still open and close, i.e. vibrate. The vibration frequency of the armature is approximately 50-150 times per second, so that the voltage fluctuations become unnoticeable, allowing the average excitation voltage to be set.

**Diagram of operation of RR-1 voltage regulator.**

Generator voltage higher than battery voltage, reverse circuit breaker contacts closed. Voltage of the generator does not exceed the permissible value. Voltage regulator contacts are closed, additional resistance is not connected to the circuit.

1. Yoke
2. Iron core
3. Spring
4. Contacts
5. Support
6. Resistor

Note: Positive Ground!
The purpose of the thick winding of the voltage regulator is to protect the generator against a strong current when the battery is discharged. The voltage drop in the discharged battery leads to a significant increase in the charging current, which results in the generator being overloaded. The increased charging current, through the coil of the core, increases the magnetizing effect of the thin winding, the armature is attracted to the core and the contacts open at a lower voltage. As the average voltage decreases, the generator current decreases. When the battery is recharged, the charging current decreases, the influence of the coil becomes weaker and the generator voltage increases. In this way, the thick winding maintains a constant charging current regardless of the battery resistance.

In addition to the thin and thick windings, a magnetic armature (Ш) is provided in the voltage regulator, made of steel with increased magnetic resistance at elevated temperatures. Its task is to maintain the winter with higher voltage and charging current than in summer. Reducing the ambient temperature reduces the magnetic resistance of the armature and a portion of the magnetic flux from the core passes through it, forming a lateral magnetic circuit. This causes the main stream to weaken. The spring tension and contact openings are only possible at higher voltages generated by the generator.

Diagram of operation of RR-1 voltage regulator. Generator voltage higher than battery voltage, reverse circuit breaker contacts closed. Voltage of the generator exceeded the permissible value - voltage regulator contacts open, current flows to the excitation winding through additional resistance.
Relay Regulator PP-31 (Реле-регулятор PP-31)

- PP-31 Mounted on Later (post 1949) M-72 Motorcycles
- Consists of Two Electromagnetic Devices: Reverse-Current Relay and Voltage Regulator
- Action of Reverse-Current Relay
  - Control lamp serves to monitor the operation of the generator and the battery. It is connected in parallel to the contacts of the reverse current relay (one wire is connected to a stationary contact, and the other is connected to armature)
- Action of Voltage Regulator Relay
  - When ignition is switched on, the battery is in good condition and the engine is not running, or when the engine is running at low speed - the indicator lamp is on, indicating that the battery is depleted
  - At medium, as well as high revs, control lamp extinguishes, indicating battery is charging
- Control Lamp Is Located in Headlight Cavity on M-72 Motorcycles
PP-31 differs from PP-1 in that it has three windings on the voltage regulator core instead of two: the main winding, i.e. the thin winding (1), winding (2), and winding (3), connected in series with the winding of the generator. In addition, the regulator has two additional resistors (7 and 50 ohms) instead of one.

The weak side of the PP-1 voltage regulator was an inadequate frequency of the vibration of the armature, due to the too low deceleration of the magnetization of the core winding. As a result, there may have been interruptions in the operation of the current collectors, and alternating currents between the battery and generator that interfere with the operation of the reverse circuit breaker. Therefore, the RR-31 uses an "accelerating resistance" (7 ohms), which increases the frequency of the contact opening.

This causes a faster voltage drop in the main winding at open contacts (when the excitation current flows through it), thereby speeding up the demagnetization of the core.

As a result of continuous vibration of the regulator jumper, the inductor winding determines the average current voltage, the value of which depends on the ratio of the time that the contacts remain open until their closure. With the increase of the speed of the generator arm, the time of the open contact is increased, resulting in the excitation current decreasing.

The increase in voltage due to the increase of the rotational speed is compensated by the reduction of the excitation current, and hence the magnetic flux of the generator. The voltage of the generator should therefore be kept constant regardless of the speed of rotation. However, the operation of the main winding of the controller depends on the excitation current, resulting in the generator's voltage increasing by 10-15%.

To prevent this, a compensating winding has been introduced. It produces a magnetizing force directed opposite to the magnetizing power of the main winding, and the resultant is a magnetizing force equal to their difference. As the speed of rotation increases, the magnetizing power of both the main winding and the compensating windings decreases, but their difference remains constant, as a result of which the generator voltage also remains constant regardless of the rotational speed.

The thick winding of the regulator protects the generator from overload in conjunction with the discharged battery - the same as the PP-1.
Adjustment of Voltage Regulator PP-31

- The voltage maintained by the voltage regulator at zero current and the rotational speed of the generator rotor 3000 rpm is 8.5 V. They are tested with a voltmeter connected to terminal Я and ground, with a strip of cardboard inserted between the contacts of the reverse circuit breaker. The adjustment is made by means of a screw (5), whose tightening causes an increase in voltage.

- The voltage maintained by the voltage regulator at 7 A current is 6.7 to 7 V. The adjustment is done as before with the screw (5). The test is done with a voltmeter and an ammeter. The voltmeter is connected to the terminal Я and to ground, and the ammeter - between the terminal Б of the controller and the wires that are connected to it. The battery should be fully charged. This connection will be used in all the following regulations.

- The voltage of the reverse circuit breaker is 6.2 to 6.8 V. When the contacts are closed, the voltmeter pointer moves. In order to regulate, the spring tension of the armature is changed by the hinge-shaped plate that secures the bottom end of the spring.

- The reverse of the switch is 0.5 to 3.5 A and is recorded by tilting the ammeter into the discharge direction while reducing the crankshaft rotation to a minimum. Reduction of the reverse current is achieved by pulling the spring of the armature and lowering the fixed contact by bending its support (bent sheet on the right side of the winding).

- In the voltage regulator the gap between the open contacts is 0.6 +/- 0.2 mm. The gap between the electromagnet and the armature is 1.6 +/- 0.3 mm. These distances are regulated by the displacement of the contact resistance frame with loosening screws.

- On the reverse circuit breaker, the contact gap is 0.75 +/- 0.15 mm and is adjusted by the bend of the contact bracket. The interval between the electromagnet and the armature is 0.5 +/- 0.25 mm and is controlled by the bend of the arm rest stop. The break between the yoke and the armature, when the contacts are closed, is 0.2 mm.
Voltage Regulator PP-31

1 - Contact screw
2 - Reverse circuit breaker
3 - Reverse circuit breaker winding
4 - Fixed contact
5 - Reverse circuit breaker
6 - Contact screw ground connection
7 - Housing
8 - Gasket
9 - Limit bar
10 - Movable contact plate
11 - Fixed contact plate
12 - Voltage regulator armature
13 - Voltage regulator main winding
14 - Lid
15 - Coil of the voltage regulator
16 - Voltage regulator yoke
17 - Voltage regulator spring
18 - Adjusting nut
19 - Resistance wire
20 - Carbon resistor
21 - Reverse current switch spring
22 - Rubber cap
23 - -
• Consists of Reverse Current Relay (5) and Voltage Regulator (13) Mounted in a Common Housing (7)

• Reverse Current Relay (5) Includes a Steel Core with Two Windings (parallel and series), yoke (5), steel armature (2) with movable contact, Stand (4) with fixed contact and spring (21) of the armature. The parallel (shunt) winding is made of copper insulated wire with a diameter of 0.17 mm and has 1,200 turns. The serial (series) winding has 15 turns made of a similar wire with a diameter of 1.81 mm. The voltage regulator includes a steel core with three windings (parallel, equalizing and correcting), yoke (16), steel armature (12) with contacts reinforced at ends of plates (10 and 11), armature spring (17) with adjusting nut (18), stop bar (9), a magnetic shunt and additional resistance (19) wire) and core (20).

• Parallel Winding Has 990 turns of Copper insulated wire with a diameter of 0.62 mm, and equalizing and correcting windings of 37 and 11 turns respectively, made of a similar wire with a diameter of 0.86 and 1.74 mm.

• Three Terminals: Ш, Я and Б
  – Must Be Connected to Generator Terminals Ш and Я and to Terminal on Ignition Lock

• Relay Attached to Motorcycle Frame Under Driver’s Seat on Right Side

1 - Contact screw, 2 - Reverse circuit breaker, 3 - Reverse circuit breaker winding, 4 - Fixed contact, 5 - Reverse circuit breaker, 6 - Contact screw ground connection, 7 – Housing, 8 – Gasket, 9 - Limit bar, 10 - Movable contact plate, 11 - Fixed contact plate, 12 - Voltage regulator armature, 13 - Voltage regulator main winding, 14 – Lid, 15 - Coil of the voltage regulator, 16 - Voltage regulator yoke, 17 - Voltage regulator spring, 18 - Adjusting nut, 19 - Resistance wire, 20 - Carbon resistor, 21 - Reverse current switch spring, 22 - Rubber cap
Voltage Regulator PP-31 (Реле-регулятор РР-31)
The voltage relay RR-30 is connected with four terminals. Terminals Я and Ш are connected to the corresponding terminals of the generator, terminal В with the battery, and the body to ground (mass). The relay-voltage regulator (PP-30) replaces voltage regulators (PP-1 and PP-31) of the M-72 motorcycle without a radical change in the internal wiring of the generator and can not be replaced by one another.
It is important to identify the exact component used on your Russian motorcycle, so that you can find the correct schematic and secure exact replacement parts.
Electronic Version of PP-1 in Old Case

Vendor ID: 003.617
List Price: € 260.00
(www.oldtimergarage.eu)

Change generator G11 “+” on body to “-” on body.

Warning!
Connected only in 1 second!

Note: Polarity of Ground Connection
Dnepr (Днепр) Early K-750 and K-750M
(with Ignition Coil B2B and Distributor PM-05 for Manual Control of Firing Angle)

**Dnepr (Днепр) Early MT-9: Manual Control of Firing Angle**
(B2B Ignition Coil and PM-05 Breaker/Distributor)

**Later MT-9: Automatic Spark Advance and MT-10**
(B201A Ignition Coil and PM-302 Breaker)

- **Horn Button**
- **Oil-Pressure Sensor**
- **Turn Signal**
- **Breaker Points (PM-302/PM-302AA)**
- **Horn**
- **Flasher**
- **Foot Brake-Light Switch**
- **Battery**
- **Ignition Coil (B201)**
- **23. Regulator (PP-31A)**