MODEL 415B HIGH VOLTAGE POWER SUPPLY

2-4. POWER INPUT

Two series transformers (T1) are available for the instrument and 100/115 vac or 230/240 vac. On the rear panel of each transformer a switch indicates the operating voltage. The transformers can be changed by altering the series transformers. To change the transformer, refer to the operating section of the instrument. To change the transformer, remove the instrument's key cover. The power required to operate the instrument is approximately 100 watt setup at 100 vac output.

2-5. Should it be necessary to change the instrument from 115 to 230 vac operation, proceed as follows:

a. Remove the panel meter and push the panel meter into the instrument to the left of the switch.

b. After the REMOVE/RESTORE lamp is illuminated, remove the knob from the switch.

c. After the instrument is set up, the panel meter is illuminated and the instrument is ready for use.
OUTPUT VOLTAGE CONTROLS

- Output range: 0 to 2500V in steps of 500V.
- 0 to 500V in steps of 100V.
- 0 to 90V in steps of 10V.
- 0 to 9V in steps of 1V.
- 0 to 1.2V in vernier.

MONITOR METER
Indicates the approximate output voltage. Accuracy is ±3% of full scale.

POLARITY
Selects either positive or negative output with respect to chassis-ground.

OUTPUT CONNECTOR
Type UG931/U connector for connecting the load to the instrument. Another output connector is located at the back of the instrument.

POWER SWITCH
Applies ac line power to control circuit and to primary of transformer.

POWER LAMP
Illuminates when power is applied to control circuit and transformer.

HIGH VOLTAGE ON LAMP
Illuminates when high voltage is available at OUTPUT connectors.

HIGH VOLTAGE STD BY RESET LAMP
Indicates completion of time delay by illuminating 30 seconds after line power is applied. HIGH voltage switch must be in STD BY RESET for completion of time delay.

HIGH VOLTAGE SWITCH
Applies voltage to high voltage rectifier when STD BY RESET lamp is illuminated.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS
Section 2  
Operating Instructions

2-1. RECEIVING INSPECTION

2-2. This instrument has been thoroughly tested and inspected before being shipped from the factory. Immediately upon receiving the instrument, carefully inspect for damage which may have occurred during shipment. If any damage is noted, follow the instructions outlined in the back of this manual.

2-3. Should any difficulties be encountered during operation of your instrument, please feel free to contact your nearest John Fluke sales representative or write directly to the John Fluke Mfg. Co., Inc. with a statement of the problem.

2-4. CONTROLS, TERMINALS, AND INDICATORS

2-5. The location and function of the front panel controls is shown in Figure 2-1.

2-6. POWER INPUT

2-7. Two power transformers (TI) are available for this instrument, 100/115 vac or 115/230 vac. On the rear panel of each instrument a decal indicates the operating voltage can be changed by altering the wiring configuration of the transformer. To change the operating voltage of the 115/230 vac transformer, refer to paragraph 2-8. Refer to Figure 2-2 for changing the operating voltage of the 100/115 vac power transformer. To gain access to the power transformer, remove the instrument’s top cover. The power required to operate the instrument is approximately 300 volt amperes at full-load output.

2-8. Should it be necessary to convert the instrument from 115 to 230 volt operation, proceed as follows. Electrical changes are shown on the decal on the underside of the top cover and on the schematic in the back of this manual.

a. Remove the jumpers between 1 and 2 and between 3 and 4.

b. Connect a jumper between terminals 2 and 3.

c. Change the fuse from a 3 ampere slow-blow to a 1.5 ampere slow-blow.

2-9. INITIAL OPERATION

2-10. The following procedure is recommended when operating the Model 415B for the first time after shipping or a long period of idleness. This procedure will minimize the possibility of damage resulting from a faulty component.

a. Connect the line plug to a 115 volts ac power source. If the instrument has been wired for 230 volt operation, connect to 230 volts ac.

WARNING!

This instrument is equipped with a 3-wire line cord, one lead of which is connected to the metal chassis. Connection to a properly-wired outlet automatically connects the chassis of the instrument to earth ground. If an adapter is used to connect the line to a two-contact outlet, the green lead extending from the adapter should be connected to a suitable ground.

b. Set the HIGH VOLTAGE switch to STDBY/RESET.

c. Set the POWER switch to ON. The ON lamp will illuminate. After approximately 30 seconds, the time-delay relay will close and the STDBY/RESET lamp will illuminate.

d. Set the second OUTPUT VOLTAGE dial to 500.

e. After the STDBY/RESET lamp illuminates, set the HIGH VOLTAGE switch to ON. Carefully observe if the HIGH VOLTAGE ON lamp illuminates and if the panel meter indicates 500 (±15) volts.
f. After the STDBY/RESET lamp illuminates, set the HIGH VOLTAGE switch to ON. The STDBY/RESET lamp will extinguish and the HIGH VOLTAGE ON lamp will illuminate. The panel meter will indicate the approximate output voltage.

NOTE!
If the overcurrent trip level has been reduced from the factory setting of 32 ma, it may be necessary to set the HIGH VOLTAGE switch to ON with a reduced output voltage setting, to prevent actuating the overcurrent trip when the HIGH VOLTAGE switch is set to ON. In this case, step d, above, would follow step f. If the HIGH VOLTAGE switch is set to ON immediately after the STDBY/RESET lamp illuminates any overload will cause the output voltage to oscillate between ON and STDBY/RESET. The oscillation can be stopped or prevented by correcting the overload condition.

g. To remove the high voltage from the output connector, set the HIGH VOLTAGE switch to STDBY/RESET.

NOTE!
When the HIGH VOLTAGE switch is in the STDBY/RESET position, there may be a voltage of 2 to 3 volts at the output connector. This voltage will be opposite in polarity to the setting of the POLARITY switch, and is due to current flow through the reference network R25 and CR4 and the absence of current in the voltage control string.

h. The output polarity of the Model 415B may be changed at any time when no load is connected to the instrument. When a load is connected, especially one that is highly reactive, the HIGH VOLTAGE switch should be set to STDBY/RESET, or the output voltage should be reduced to 500 volts, before changing the output polarity. If the polarity is switched at high output voltages with reactive loads, the POLARITY switch may be damaged.

i. The Model 415B is protected from overload damage by an overcurrent protection circuit which removes power from the high voltage rectifiers at an output current of 32 milliamperes, or at the value set during calibration of the instrument. When the overload trip is actuated, the HIGH VOLTAGE ON lamp will extinguish. The high voltage may be re-applied to the output connectors as follows:

1) Set the HIGH VOLTAGE switch to STDBY/RESET. After approximately 30 seconds the STDBY/RESET lamp will illuminate.

2) Set the HIGH VOLTAGE switch to ON. The STDBY/RESET lamp will extinguish and the HIGH VOLTAGE ON lamp will illuminate. The output voltage will be available at the output connectors.

CAUTION!
If the output exceeds 593 volts immediately set the HIGH VOLTAGE switch to STDBY/RESET.

If the output is within tolerance the instrument may be operated as in paragraph 2-11. If the output is not within tolerance, troubleshoot the instrument as described in paragraph 4-35.

2-11. OPERATING PROCEDURES

a. Set the POWER switch to ON. The ON lamp will illuminate.

b. Set the HIGH VOLTAGE switch to STDBY/RESET. After approximately 30 seconds the time-delay relay will close and the STDBY/RESET lamp will illuminate.

c. Set the POLARITY switch to the desired polarity.

d. Set the OUTPUT VOLTAGE dials to the desired output.

CAUTION!
Rapidly decreasing the setting of the OUTPUT VOLTAGE dials with the high voltage on may damage the sampling string resistors. When dialing down the output voltage, pause approximately 1/2 second in each switch position.

e. Connect the load circuit securely to the output connector. Check the external circuit for conflicts in grounding before applying power to the load.

WARNING!
This power supply can produce lethal voltage. Always set the HIGH VOLTAGE switch to STDBY/RESET and wait until the output voltage has decayed to zero before connecting or disconnecting the load.
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**NOTE!**
To obtain best output stability from the Model 415B, the HIGH VOLTAGE switch should be set to STDBY/RESET and the POWER switch left ON. This will maintain an even distribution of heat within the unit and prevent the need for recurrent warmups. For highest stability applications, the OUTPUT VOLTAGE dials should be set to the desired voltage and the HIGH VOLTAGE switch left ON.

2-12. APPLICATIONS

2-13. Calibration of Meters

2-14. The Model 415B may be used for direct calibration of dc instruments to an accuracy of 0.25% or 100 millivolts (whichever is greater) at 3100 cardinal points, 1 volt apart, from 0 to 3099 volts. The vernier dial provides an additional 1.2 volts of range for calibration between cardinal points. Proceed as follows:

a. Set the POLARITY switch to the desired polarity.
b. Connect the instrument being calibrated firmly to the power supply. Check the external circuit for conflicts in grounding before applying power to the load.
c. Set the HIGH VOLTAGE switch to ON. The STDBY/RESET lamp will extinguish and the HIGH VOLTAGE ON lamp will illuminate.
d. Set the first four OUTPUT VOLTAGE dials to the desired cardinal point. Use the last dial if a calibration point between the one volt cardinal points is desired.
e. To remove the output voltage from the output connector, set the HIGH VOLTAGE switch to STDBY/RESET.

2-15. When used with a John Fluke differential voltmeter and voltage divider, the 415B is capable of calibrating dc instruments from 0 to 3100 volts with an accuracy of 0.01% to 0.06% with 5 millivolts resolution. For calibration of instruments from 0 to 1100 volts, proceed as follows:

a. Set the POLARITY switch to the desired polarity.
b. Connect the instrument being calibrated firmly to the power supply. Check the external circuit for conflicts in grounding before applying power to the load.
c. Connect a John Fluke Model 80N-5 Voltage Divider to the instrument being calibrated and connect the differential voltmeter to the voltage divider output terminals.
d. Set the differential voltmeter to measure the voltage at the desired calibration point, considering the ten-to-one division ratio of the voltage divider.
e. Set the HIGH VOLTAGE switch to ON. The STDBY/RESET lamp will extinguish and the HIGH VOLTAGE ON lamp will illuminate.
f. Null the differential voltmeter by adjusting the OUTPUT VOLTAGE dials. The accuracy of the voltage measured is from ±0.02% to ±0.06%, according to the accuracy of the differential voltmeter and voltage divider used.
g. Set the HIGH VOLTAGE switch to STDBY/RESET.
h. Repeat steps d. through g. for as many calibration points as desired.

2-16. For calibration of instruments from 1100 volts to 3100 volts, proceed as follows:

a. Set the POLARITY switch to the desired polarity.
b. Connect the instrument being calibrated firmly to the power supply. Check the external circuit for conflicts in grounding before applying power to the load.
c. Connect a John Fluke Model 80N-5 Voltage Divider to the instrument being calibrated and connect the differential voltmeter to the voltage divider output terminals.
d. Set the differential voltmeter to measure the voltage at the desired calibration point, considering the ten-to-one division ratio of the voltage divider.
e. Set the HIGH VOLTAGE switch to ON. The STDBY/RESET lamp will extinguish and the HIGH VOLTAGE ON lamp will illuminate.
f. Null the differential voltmeter by adjusting the OUTPUT VOLTAGE dials. The accuracy of the voltage measured is from ±0.02% to ±0.06%, according to the accuracy of the differential voltmeter and voltage divider used.
g. Set the HIGH VOLTAGE switch to STDBY/RESET.
h. Repeat steps d. through g. for as many calibration points as desired.

2-17. Operation with a Reference Divider

2-18. When the output of the Model 415B is compared to a standard cell by way of a reference divider, the Model 415B can be set to provide voltages of an accuracy greater than the inherent accuracy of the instrument. When used with the Model 750A Reference Divider and the Model 845AB Voltmeter/Null Detector, the Model 415B can provide voltages 0.1, 0.5, 1.0, 5, 10, 100, 500, 1000, and 1100 volts which have an accuracy of 10 to 20 ppm, and are traceable to the National Bureau of Standards. Connect the equipment as shown in Figure 2-3 and proceed as follows:

a. Set the Model 415B HIGH VOLTAGE switch to STDBY/RESET and the POWER switch to ON.
b. Set the Model 750A STANDARD CELL dials to the voltage value of the standard cell being used.
c. Set the Model 750A INPUT VOLTAGE switch to 1100 volts or the highest voltage desired.
Figure 2-3. OPERATION WITH A REFERENCE DIVIDER
d. Set the Model 750A COARSE and FINE controls to mid-position.

e. Set the Model 415B POLARITY switch to the desired polarity and the OUTPUT VOLTAGE controls to same voltage value as the Model 750A INPUT control.

f. Set the Model 845B controls as follows:

<table>
<thead>
<tr>
<th>Control</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>POWER</td>
<td>ON</td>
</tr>
<tr>
<td>OPR/ZERO</td>
<td>OPR</td>
</tr>
<tr>
<td>RANGE</td>
<td>To reduced sensitivity (1 volt for example)</td>
</tr>
</tbody>
</table>

g. Set the Model 415B HIGH VOLTAGE switch to ON. Throw the STANDARD CELL switch on the Model 750A to MOMENTARY and note the deflection on the Model 845AB. Then adjust the Model 415B OUTPUT CONTROLS, including the vernier, to achieve zero indication on the Model 845AB. Increase sensitivity of the Model 845AB as null is approached.

h. Using the COARSE and FINE controls on the Model 750A, adjust for a final null on the 10 microvolt range of the Model 845AB.

i. Calibrated output voltages are now available at the Model 750A OUTPUT VOLTAGE terminals. The desired voltage value is selected with the Model 750A OUTPUT VOLTAGE control.

2-19. Leakage Current Measurements

2-20. The Model 415B, in conjunction with any John Fluke differential voltmeter, may be used to determine leakage current at high voltage in insulators, capacitors and test instruments. Proceed as follows:

a. Connect the equipment as shown in Figure 2-4. The protection circuit shown in Figure 2-4 provides protection to the voltmeter by limiting the input to less than one volt in the event of a short in the component under test. The resistors must be non-inductive (composition, Allen Bradley type).

b. Set the differential voltmeter to measure 100 millivolts.

c. Set the HIGH VOLTAGE switch to ON. When the HIGH VOLTAGE lamp illuminates gradually increase the output of the Model 415B until the desired test voltage or limit of leakage current is obtained.

d. An indication of 100 millivolts on the voltmeter indicates a leakage current of 0.1 microamperes and corresponds to a measured resistance of $3 \times 10^{10}$ ohms when 3000 volts is applied from the Model 415B.

2-21. Circuit Protection

2-22. The overcurrent protection circuit of the Model 415B is adjusted at the factory to operate 32 milliamperes load current. This adjustment is accessible through the top cover and may be set to operate at other load currents up to 35 milliamperes. To re-adjust the overcurrent circuit to operate at a load current other than 32 milliamperes, refer to paragraph 4-33.

![Figure 2-4: LEAKAGE CURRENT TESTING](image-url)
Section 3

Theory of Operation

3-1. INTRODUCTION

3-2. This section describes the theory of operation of the Model 415B. Refer to the block diagram, Figure 3-1, and to the functional schematic diagram in conjunction with this text. The schematic is located in the rear of this manual, following Section V.

3-3. BLOCK DIAGRAM ANALYSIS

3-4. The Model 415B high voltage power supply consists basically of a power transformer, high-voltage rectifier, series pass regulator, error amplifier, reference divider and voltage control resistor string. It also includes a time delay circuit, auxiliary power supply, +125 volt regulator, temperature-compensated reference voltage, overcurrent protection circuit and a voltmeter.

3-5. The input line voltage passes through the power transformer and is converted to output dc voltage and auxiliary dc support voltages. A 30-second delay is imposed on application of ac to the high voltage rectifier.

3-6. The high voltage dc appears across the series pass tubes and the output terminals. The magnitude of output voltage is set by varying the resistance of the voltage control string, and is maintained at this level by varying the conduction of the series pass tubes in response to control signals from the error amplifier.

3-7. The voltage control circuits include the reference tube, reference network, voltage control resistor string and the error amplifier. The reference tube provides a constant current to the reference network and voltage control resistors which are connected in series to the common output buss. One input to the error amplifier is the summation junction of the reference network and the voltage control string. The other input is connected to the positive output buss. Any voltage difference between the two inputs is amplified, and used to drive the series pass tubes which maintain the output voltage constant. The front panel meter provides an indication of output level.

3-8. CIRCUIT DESCRIPTIONS

3-9. Time Delay

3-10. When the POWER switch is set to ON, ac is applied to the series pass tube filaments and to the auxiliary supply. There is a 30 second delay before high voltage can be supplied. This permits the auxiliary voltages to reach operating level and insures that voltage control circuits have control when high voltage is applied. This delay is provided by K1 on the High Voltage Rectifier Assembly; K1 operates only if the HIGH VOLTAGE switch S2 is in STDBY/RESET position. The dc output common buss is also open circuited when power is first turned on. To close the output buss, the time delay must be completed and relay K4 operated by the HIGH VOLTAGE switch.

3-11. In referring to the functional schematic, it should be noted there are two ground return symbols in the primary circuit of the power transformer. The ac return (\( \phi \) ac) connects the low side of the primary to the low side of the power line through the POWER switch S1. The dc return (\( \phi \) R) completes the return path of the half-wave rectifier consisting of CR1, R1, R3 and C1. This rectifier supplies dc to operate relays K2, K3 and K4 on the High Voltage Rectifier P/C Assembly. When the time delay cycle is completed, dc is supplied to K2. Contact K2B opens and removes the time delay relay from the circuit. Contacts K2A and K2C close and K2A illuminates the STDBY/RESET lamp. When the HIGH VOLTAGE switch is set to ON position, the HIGH VOLTAGE lamp illuminates and relays K3 and K4 are operated from contact K2C. Contacts K3A and K3B complete the ac circuit of the high voltage rectifier. Contacts K4A and K4B complete the dc output circuit.

3-12. High Voltage Rectifier and Series Pass

3-13. The multitap high voltage winding of the power transformer provides voltage to the high voltage rectifier according to the position of the first OUTPUT VOLTAGE switch. The multitap feature provides approximate control of the unregulated dc output of the
high voltage rectifier and minimizes the power dissipation required of the series pass tubes at low output voltage. The high voltage rectifier filter consists of CR2 through CR23 on the High Voltage Rectifier P/C Assembly in addition to C7, C8 and R1 through R6 on the Bleeder P/C Assembly. This circuit forms a voltage doubler configuration which provides filtered but unregulated dc voltage to the series pass tubes V1 and V2. The parallel-connected series pass tubes maintain the output voltage at the value set on the control dials by altering tube conduction in response to control signals from the error amplifier.

3-14. Error Amplifier

3-15. The error amplifier consists of Q6, Q7 and Q8 on the Amplifier P/C Assembly and Q1 through Q4 on the Series Pass P/C Assembly and their associated circuitry. Q7 and Q8 form a differential amplifier. The input to Q7 is from the positive output buss; the input to Q8 is from the summation point at the junction of the voltage control resistors and the reference network. Any voltage change at the output buss appears as a voltage difference between the bases of Q7 and Q8 and alters the collector current of Q8. This change appears as error signal at the base of the common emitter amplifier Q6. The output of Q6 is fed back to the base of Q7 for loop stabilization and to the compound-connected emitter follower stage Q3 and Q4 located on the Series Pass P/C Assembly (A5).

3-16. Q3 and Q4 provide current drive and impedance match between the high collector impedance of Q6 and the low emitter impedance of Q2. The cascaded common base amplifiers Q1 and Q2 provide the voltage gain necessary to swing the grids of the series pass tubes, V1 and V2, through the required range.

3-17. Reference Tube and Resistor Network

3-18. The reference tube, VI, is a specially selected and aged type 83A1. VI is provided with a temperature-compensation network, R14 and R15, so that its output is a constant voltage. Since the summation point is always at zero volts, VI causes a constant current to flow through the reference network. This same constant flows through the voltage control resistors, and the output voltage is equal to the IR drop across these resistors. The output voltage may thus be precisely controlled by varying the resistance of the voltage control string.

3-19. Auxiliary Supply

3-20. AC voltage for both positive and negative auxiliary dc supplies is provided by a single transformer winding. One terminal of this winding is connected to the positive output buss; the other terminal is connected via R2 to the junction of CR1 and CR2. Diodes CR1 and CR2, on the Series Pass P/C Assembly, and C1 and C2, on the Amplifier P/C Assembly comprise a voltage doubler. The output of the doubler is impressed across a network consisting of R3, R4 and R5, and zener diodes CR3 through CR6. This arrangement provides regulated dc voltages of +95, +20, +10 and -110 volts. The raw dc +125 volt output of the supply is fed to the regulator on the Amplifier P/C Assembly.

3-21. +125 Volt Regulator

3-22. The +125 volt regulator consists of Q1 through Q5 and their associated circuitry on the Amplifier P/C Assembly. Q4 and Q5 comprise a differential amplifier. Q3 is an emitter follower regulator which serves as a 100 volt source for the emitter of Q3 and the collector of Q4. The bases of Q4 and Q5 are held at a constant 83 volts by the reference tube V1. The base of Q4 also samples the +125 volts dc through the divider R8 and R9. Any difference in voltage between the bases of Q4 and Q5 appears as error signal at the base of Q3. Q3 provides further gain to the signal which is applied to the series regulator Q1. Zener diode CR1 provides regulated dc to Q3 and bypasses a part of the current to decrease dissipation of Q1.

3-23. Overcurrent Protection

3-24. Protection to the instrument from damage by excessive current is provided by relay K1 located on the Bleeder P/C Assembly. K1 is in series with the common output lead and is normally adjusted to operate at 32 milliamperes by R5 located on the High Voltage Rectifier P/C Assembly. Adjustment R5 divides the load current between K1 and the relay shunting resistors R5 and R6. The contacts of K1 are connected across the coil of K2 on the High Voltage Rectifier P/C Assembly and de-energize this relay. In order for high voltage to be re-applied the overload must be removed and the time delay permitted to complete its cycle.

3-25. ACCURACY

3-26. The main sampling string resistors in the Model 415B are accurate to within ±0.1%. The accuracy of the Model 415B, however, is specified as ±0.25% because the instrument accuracy also depends upon the repeatability and stability of the reference voltage and the length of on-time of V1. The output voltage of V1 changes slightly with time due to aging. The accuracy of the instrument will remain within ±0.25% for greater than 30 days. The calibration accuracy may be maintained better than ±0.25% if the supply is recalibrated more often than the usual calibration period of 30 days.

3-27. The overall accuracy of the meter in the Model 415B is approximately ±3% of meter input, including the tolerances of multiplying and shunting resistors. However, the calibrated voltage controls should be relied upon to indicate the value of the output voltage. For example, if an output voltage of 1000 volts is selected, the meter will indicate between 970 volts and 1030 volts (±3% of 1000-30). However, the actual output voltage will be between 997.5 volts and 1002.5 volts (±0.25% of 1000±2.5).

3-28. All calibrated power supplies have an accuracy limit (floor) as the output voltage approaches zero. This floor is caused by zero shift in the error amplifier, contact resistance in the sampling string circuit, and the accuracy of the voltage-control resistors used for the least significant digits. The Model 415B has an accuracy of ±0.25% or 100 mv, whichever is greater, with the vernier at zero. Thus, the ±0.25% accuracy is valid down to 40 volts.

Rev. 1
Figure 3-1. MODEL 415B BLOCK DIAGRAM
Figure 3-1. MODEL 415B BLOCK DIAGRAM