USER MANUAL
W8ZR Stepper Motor Controller

I. Overview

The W8ZR Stepper Motor Controller is a general purpose controller for a unipolar (6 wire) stepper motor. The circuit has several switch-selected options that make it versatile and easy to use. The features of the stepper motor controller include:

1. Optical isolation between the motor driver circuit and the logic circuits, providing isolation from motor-induced noise and RF interference. The circuit is intended for use in strong RF or other noisy environments.

2. An on-board timer that disconnects power from the stepper motor 0.2 seconds after the last control pulse has been received. This feature can be disabled if desired. In addition, the power-off feature can be controlled by an external enable TTL LOW level

3. Motor steps and direction are controlled by only two wires: (1) a step input, which can be a rising or falling edge TTL pulse or square wave; and (2) a rotation direction determined by a TTL HI (CW) or TTL LOW (CCW) level.

4. An on-board +5V regulator, that can be used to power external control circuitry in applications that do not require complete optical isolation.

5. Stepper motors of from 5 - 28 Volts may be controlled, with up to 1A per phase.

6. On-board circuitry for interfacing to an end-of-rotation optical interrupter.

II. Circuit Description

As shown on the circuit diagram, the stepper motor is controlled by U201, which consists of four hi-current (1.5A) switches in a single DIP package. Each section of U201 contains a built-in safety diode, which protects U201 from inductive motor spikes. Resistors R207 and R215 limit the current through the center tap of the motor windings for power supply voltages Vs that exceed the motor ratings; these resistors are jumpered if no current-limiting is needed. U210 is a +5 Volt regulator for the internal circuitry of U201. As described below, U210 can also be used (in other applications) to power the rest of the control circuit as well as any external circuits

The four sections of U201 are controlled by the open collector outputs of opto-couplers U203, U206, U207, U208. When the LEDs in the opto-coupler are illuminated, the output photo darlingtons conduct, driving low the inputs of U201 and disabling the respective motor windings.

Note that all ground connections on the output side of the opto-couplers are shown as earth grounds, whereas all the grounds on the input side of the opto-couplers are shown as chassis grounds. These separate grounds provide complete electrical isolation between the input and output sides of the opto-couplers to prevent interaction between the circuits. If this degree of isolation is not needed in other applications, then the two grounds can be jumpered together at JP1. By closing switch SW4, the regulated +5V from the output of U210 can then be used to power the controller logic circuits. The +5V also appears at pin 1 of J202, for use by external circuitry.

The sequencing waveforms for the stepper motor are determined by dual flip-flops U205a and U205b, in combination with XOR gates U204a and U204b. The four TTL outputs of U205a and U205b are applied to one set of inputs of NAND gates U202a-U202d. When the other inputs of these gates are HI, the gates just pass through the TTL input levels to the LEDs of U203 and U206-U208. When the other inputs of U202a-U202d are LO, the output of the gates is low. Thus U202a-U202d can be used to disable or enable the motor driver circuit, depending on the state of the control inputs.

There are three ways that gates U202a-U202d can be used to enable or disable the motor, depending on the settings of DIP switches SW2 and SW3. With both switches open, the output of XOR gate U204d is always HI, thus permanently enabling U202a-U202d. When SW2 is closed and SW3 is open, then a LO on pin 4 of J202 turns off Q201, which causes U204d to output a HI to U202a-U202d. When SW2 is open and SW3 is closed, then the state of XOR gate U204d is controlled by the output at pin 9 of U209b.

U209a and U209b are twin 555-type timers configured as a retriggerable monostable multivibrator. The purpose of these timers is automatically to enable the motor while step pulses are being received, and then to disable the motor after the step sequence is completed. The timer triggers on the initial motor step pulse appearing at the output of U204c, and outputs a HI at pin 9 of U209b. This output remains high for about 0.2 seconds after the last step pulse is received, a time constant set by R223 and C213.

The motor is stepped by TTL level pulses appearing on pin 5 of J202. XOR gate U204c is used to set the polarity of the triggering, according to the setting of SW1. The flip-flops trigger on either rising or falling edges of the input waveform; the EZ-Tuner uses rising edges.

Pin 3 of J202 is a limit detect output to the microcontroller. Stepper motors generally have an optical or mechanical switch that indicates when one end of rotation is reached (e.g., when a variable capacitor is fully meshed). Resistor networks R221, R222 and C211, C212 provide biasing and conditioning for this limit switch.

III. Interfacing and Hookup

There are four connector headers on the circuit board, J201, J202, and J203, and J204. The only subtlety involved in the hookup is to understand that the logic circuit of the controller is completely isolated (through optical isolators) from the stepper motor and its power source. This isolation provides great noise immunity and is one of the main features of this circuit. However, to take full advantage of this isolation, the stepper motor and the controller require separate, independent power supplies. These isolated power supplies should have separate grounds as well as "hot" outputs.

In the event total isolation is not required, then a single power supply can be used for both the motor and the logic circuit. Switch SW4 selects this option, and a jumper JP201 ties the two grounds together. This option is described in detail below.

The headers have the following pinouts and functions:

J201: The power supply for the stepper motor (and, optionally, for the controller circuitry) connects here. The acceptable voltage range can vary from 5V to 30V, depending on the requirements of the particular motor. Note that circuit board has provision for two current-limiting power resistors, R207 and R215. These are included in case the power supply voltage is greater than the voltage requirements of the stepper motor. In that event, choose R207 and R215 to limit the current through the motor to its rated value. If no current limiting is required (e.g., using a 12V power supply with a 12V stepper motor), then current-limiting resistors are not needed and R207 and R217 should be jumpered with hookup wire. The circuit diagram shows 12Ω/5W resistors for R207 and R215; these are the values for an 11.2V/0.44A stepper motor when a +24VDC power supply is used.

Note that if Switch SW4 is closed and jumper JP201 is installed, then the power supply connected to J201 can be used to power the stepper motor logic circuit, as well as to power the stepper motor itself. However, if complete isolation between the logic circuit and the stepper motor is desired, this switch should be left open and jumper JP201 should not be installed

Pin 1: +5-30VDC (depends on motor requirements)
Pin 2: GND

J202: This connector is used for controlling the stepper motor.

Pin 1: +5V DC. If complete isolation between the motor and the logic circuit is desired (SW4 and JP201 open), then +5VDC should be applied to this pin to control the controller's logic circuitry. If isolation is not necessary (SW4 and JP201 closed), then +5VDC from the controller's on-board voltage regulator is available at this pin to power external circuitry. The maximum current that can be drawn from this pin is 0.9A

Pin 2: Rotation sense is controlled by a TTL level on this pin; HI=CW and LO=CCW.

Pin 3: Users often desire to use an optical interrupter to sense "end of rotation." On-board circuitry for an optical interrupter is provided for this purpose, and the sense output (LO= end of rotation) is available at this pin. See J204 description.

Pin 4: Remote Enable. A TTL LO level on this pin will enable the stepper circuitry, if this option is selected with Switches SW2 and SW3. If remote enable is not used, an on-board timer will disable the controller 0.2 sec after the last step pulse is received. The controller will automatically "come to life" when another step pulse is received.

Pin 5: A TTL rising or falling edge on this pin (selectable by SW1) will cause the stepper motor to advance one step.

Pin 6: Logic Ground. Note that this is a separate ground from the Stepper power supply ground on pin 2 of J201.

J203: The six wires from the stepper motor connect here.
(Refer to the schematic diagram for stepper winding details)

Pin 1: A	Pin 4: B
Pin 2: AC	Pin 5: BD
Pin 3: C	Pin 6: D

J204: End-of-Rotation Optical Interrupter Interface

Pin 1: (Sense) connect to the collector of the phototransistor
Pin 2: (LED) connect to the LED anode
Pin 3: (GND) connect to the LED cathode and phototransistor emitter

DIP Switch SW201 (SW1-SW4):

SW1: Step Polarity
closed = motor steps on rising edge
open = motor steps on falling edge

SW2-SW3: Enable Status
SW2 open, SW3 open = controller always enabled
SW2 open, SW3 closed = auto mode (controller times out after 0.2 sec)
SW2 closed, SW3 open = controller enabled by LO on J202 pin 4)

SW4: Power Supply Isolation
Closed = controller logic powered by J201 power supply and on-board regulator (Jumper JP201 must be connected)
Open = controller logic powered by J202

IV. Assembly Notes and Parts List

Assembly of the controller board is very straightforward, with no surprises or difficult steps. It is good construction practice to orient the resistors so their color codes are lined up in the same direction. Be careful to observe the polarity of C213 and C215, noting that a "+" is marked on the silk-screened legend. Also, be sure the notches on the ICs are oriented as shown on the silkscreen.

Make sure the four connectors and ICs are snug against the circuit board, before you solder them in place. You can tack solder opposing pins to position these components and then solder the remaining pins. After the board is wired, clean the solder joints with isopropyl (rubbing) alcohol and Q-Tips, and check each connection for cold solder joints or solder bridges. This is a tried-and-tested circuit that has been duplicated many times, and you shouldn't have any trouble getting it working if you take care with your soldering.

Notes:

(1) All resistances 1/4 W metal film, unless otherwise noted. Values in ohms.
(2) Headers are Molex type 0.156" or 0.100" spacing, single in-line type.
(3) R207 and R215 are selected to limit current through the stepper motor. Suggest 5W rating.
(4) unless noted otherwise, capacitors are ceramic disc, 50V min. rating

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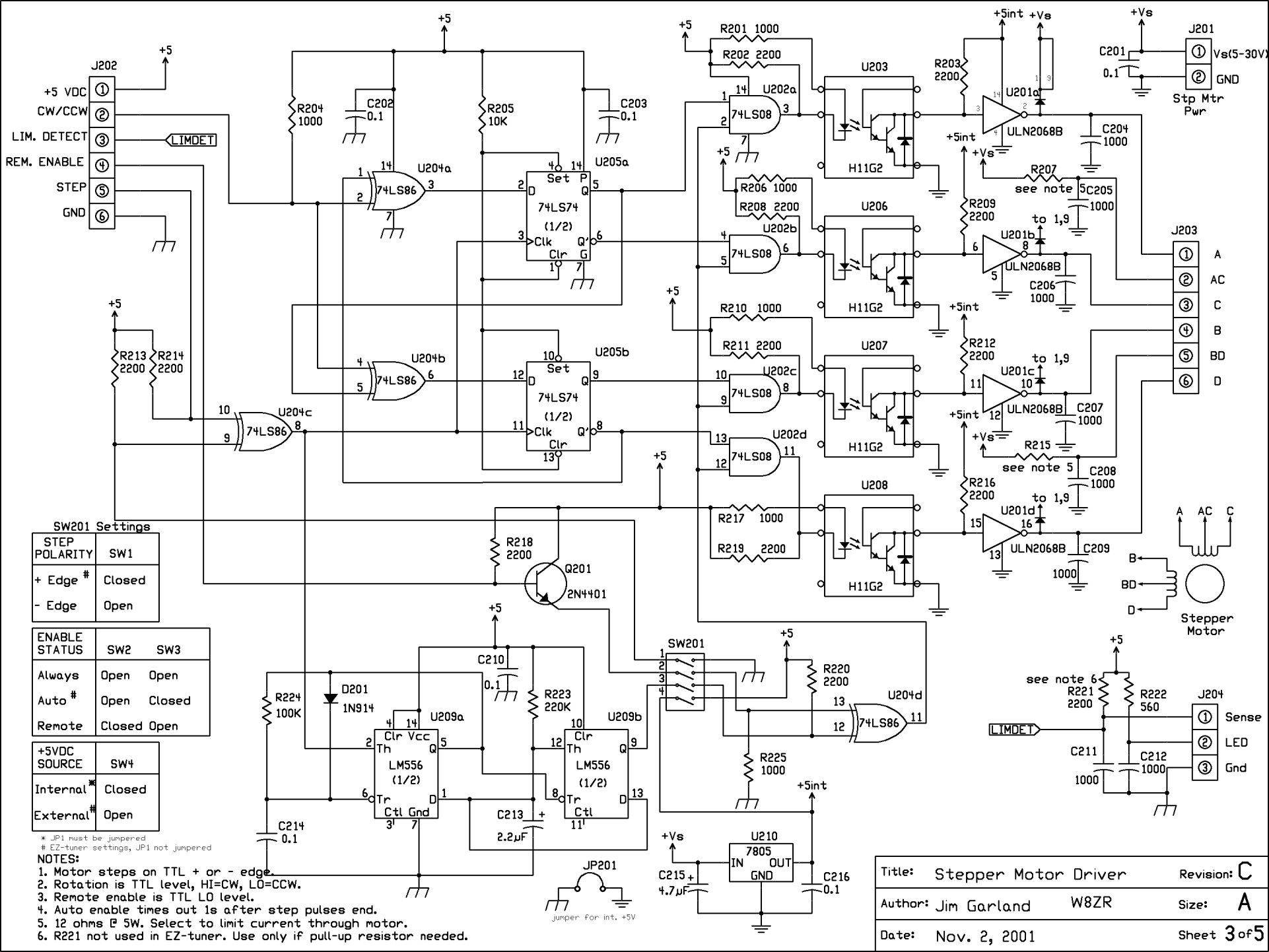
Ref. ID	Value
C201	0.1 µF
C202	0.1 µF
C203	0.1 µF
C204	1000 pF
C205	1000 pF
C206	1000 pF
C207	1000 pF
C208	1000 pF
C209	1000 pF
C210	0.1 µF
C211	1000 pF
C212	1000 pF
C213	2.2 µF/35V electrolytic or tantalum
C214	0.1 µF
C215	4.7 µF/35V electrolytic or tantalum
C216	0.1 µF
D201	1N914, 1N4148 or equiv.
J201	Molex .156" Header 2-pin
J202	Molex .100" Header 6-pin
J203	Molex .156" Header 6-pin
J204	Molex .100 Header 3-pin
JP201	Wire jumper
Q201	2N4401, 2N2222, or equiv.
R201	1000 Ω (brown-black-red)
R202	2200 Ω (red-red-red)
R203	2200 Ω (red-red-red)
R204	2200 Ω (red-red-red)
R205	10 KΩ (brown-black-orange)
R206	1000 Ω (brown-black-red)
R207	12 Ω/5W(special - see note 3)
R208	2200 Ω (red-red-red)
R209	2200 Ω (red-red-red)
R210	1000 Ω (brown-black-red)
R211	2200 Ω (red-red-red)
R212	2200 Ω (red-red-red)
R213	2200 Ω (red-red-red)
R214	2200 Ω (red-red-red)
R215	12 Ω/5W (special - see note 3)
R216	2200 Ω (red-red-red)
R217	1000 Ω (brown-black-red)
R218	2200 Ω (red-red-red)
R219	2200 Ω (red-red-red)
R220	2200 Ω (red-red-red)
R221	2200 Ω (red-red-red)
R222	560 Ω (green-blue-brown)
R223	220 KΩ (red-red-yellow)
R224	100 KΩ (brown-black-yellow)
R225	1000 Ω (brown-black-red)
SW201	4-Position DIP Switch
U201	ULN2068B or ULN2069B
U202	74LS08
U203	H11G2
U204	74LS86
U205	74LS74
U206	H11G2
U207	H11G2
U208	H11G2
U209	LM556
U210	7805 volt. reg.


J202
+5 VDC
CW/CCW
LIM. DETECT
REM. ENABLE
STEP
GND
LIMDET
R204 1000
C202 0.1
R205 10K
C203 0.1
U204a
U205a
74LS86
74LS74 (1/2)
Set
Clr
R213 2200
R214 2200
U204b
U205b
U204c
R201 1000
R202 2200
U202a
74LS08
R206 1000
R208 2200
U202b
R210 1000
R211 2200
U202c
R217 1000
R219 2200
U202d
U203
U206
U207
U208
H11G2
+5int
+Vs
R203 2200
R207 see note 5
R209 2200
R212 2200
R215 see note 5
R216 2200
U201a
U201b
U201c
U201d
ULN2068B
C204 1000
C205 1000
C206 1000
C207 1000
C208 1000
C209 1000
to 1,9
J201
C201 0.1
Vs(5-30V)
GND
Stp Mtr Pwr
J203
A
AC
C
B
BD
D
Stepper Motor
R218 2200
Q201
2N4401
SW201 Settings
STEP POLARITY | SW1
+ Edge # | Closed
- Edge | Open
ENABLE STATUS | SW2 | SW3
Always | Open | Open
Auto # | Open | Closed
Remote | Closed | Open
+5VDC SOURCE | SW4
Internal * | Closed
External # | Open
* JP1 must be jumpered
# EZ-tuner settings, JP1 not jumpered
SW201
R220 2200
U204d
R225 1000
C210 0.1
R223 220K
R224 100K
D201
1N914
U209a
U209b
LM556 (1/2)
Clr Vcc
Th
Tr
Ctl Gnd
C213 2.2µF
C214 0.1
JP201
jumper for int. +5V
U210
7805
IN
OUT
GND
C215 4.7µF
C216 0.1
see note 6
R221 2200
R222 560
J204
Sense
LED
Gnd
C211 1000
C212 1000
NOTES:
1. Motor steps on TTL + or - edge.
2. Rotation is TTL level, HI=CW, LO=CCW.
3. Remote enable is TTL LO level.
4. Auto enable times out 1s after step pulses end.
5. 12 ohms @ 5W. Select to limit current through motor.
6. R221 not used in EZ-tuner. Use only if pull-up resistor needed.
Title: Stepper Motor Driver
Revision: C
Author: Jim Garland W8ZR
Size: A
Date: Nov. 2, 2001
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