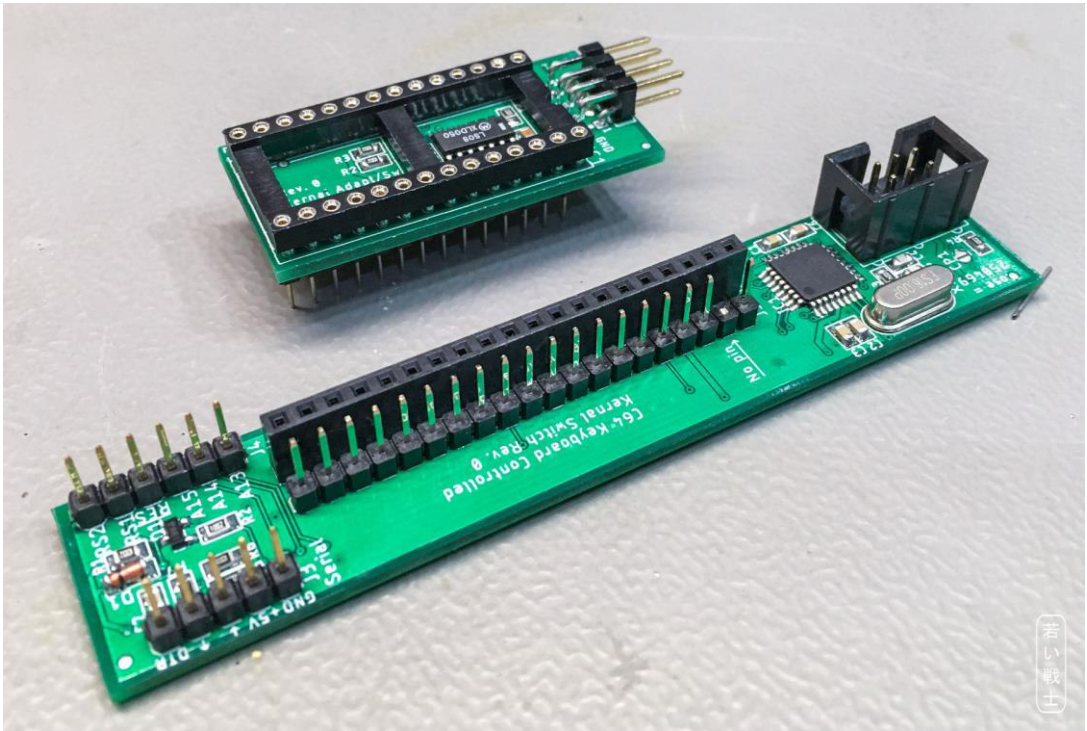
Project Documentation

Commodore C64 – Keyboard Controlled Kernal Switch

Project number: 128

Revision: 0

Date: 14.06.2019



Disclaimer

The usage of the described hardware and the information required in the documents are at own risk. The author cannot be made liable for the correctness of the development and/or the documentation. It is assumed, that the assembly and installation of the hardware and software is performed by a person of sufficient expertise. The work has to be carried out with care, since it might risk damaging the hardware or the computer it is to be installed in.

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C64 Keyboard Controlled Kernal Switch Rev. 0

Module Description

Introduction

The C64 Keyboard controlled Kernal switch is a module, which is (passively) watching some the scan activity of the C64 keyboard and is capable of setting the higher address bits for Kernal adapters, like project number 123 (C64 Kernal-Adaptor/Switch (Short Board), up to 7 Kernals), project number 124 (C64 Kernal-Adaptor/Switch (Long Board), Up to 8 Kernals) and/or the character set adaptor project number 126 (C64 CHARSET-Adaptor/Switch, 16 character sets). A $\overline{\text{RESET}}$ -signal is provided to reset the C64 while/after selecting the Kernal via the three most significant EPROM address bits. Two excess IO-pins of the processor Atmel ATmega328p are routed to the pin header J4 for future use.

The ATmega328p can be configured as Arduino Uno, a pin header is providing access to the serial interface for uploading the compiled Arduino sketches. Initial programming will be performed via the ICSP connector J2.

The board fits between the keyboard connector of the C64 mainboards and the keyboard itself. All keyboard signals are interconnected, some keyboard signals are monitored by the micro controller.

Usage of the Kernal Switch

To make use of the Kernal Switch, more than one Kernal should be programmed to the EPROM on the EPROM adaptor. The Kernal can be selected by Pressing RESTORE and a number key simultaneously. The Kernal, determined by the number will be selected and the C64 will be reset. This selection is non-volatile and will be effective even after switching off the C64.

Holding down the RESTORE key for a couple of seconds without pressing a number, a reset of the C64 is performed.

In case an empty Kernal memory slot is selected, the C64 will crash, since there is no Kernal found. In this case, the C64 does not perform a keyboard scan and since the Kernal Switch is only listening to the keyboard scanning, but does not perform any keyboard scan, the Kernal number cannot be set manually anymore. After several seconds without keyboard scan, the Kernal switch will automatically recover to the first Kernal and reset the C64. This will recover the system.

Some cartridges will not perform a keyboard scan (such as the Dead Test cartridge). The recovery mechanism will conflict with this kind of cartridge and reset the C64 after several seconds. To circumvent this problem, it is possible to deactivate the Kernal switch by pressing RESORE 0 (zero!). This will switch to the first Kernal and set a non-volatile flag. After switching off the C64 and inserting the cartridge, no keyboard activity timeout will be performed, the cartridge will work as usual.

After the cartridge was removed, the first Kernal will be executed and (of course) a normal keyboard scan will be performed. Selecting a Kernal with RESTORE and a number will activate the Kernal Switch again and the new selection will be effective.

Assembly

It is assumed, that the person, who assembles the Kernal Switch is experienced in soldering. First the SMD parts should be soldered, the bottom entry receptacle J1 should be soldered last. It can be aligned to the holes in the board using the pin header J5. Pin2 of J2 has to be clipped and the connector has to be inserted into the holes from the solder side. Then J1 has to be placed over those pins and the connector has to be aligned in a way, that it is centered on the J1 silk screen drawing and the SMD pins are in the middle of the solder pads. Then one pin has to be soldered. Then the connector might need to be corrected and a second pin can be soldered. If the pin header inserts easily from the bottom, all other pins can be soldered.

Finally, the through hole parts have to be soldered.

Cloe (or leave open) the solder bridge CP1, depending whether a short board (ASSY 250469, close CP1) or a long board (all other ASSY numbers, leave CP1 open) is present in the C64.

To prevent the components of the Kernal Switch from making contact with any parts of the C64 mainboards, the area top and bottom of the keyboard connectors can be taped with duct or gaffer tape.

After being completely assembled, the micro controller IC1 (ATmega238P) has to be programmed. Refer to document number 128-6-05-00 (Programming Guide).

For wiring the Kernal Adaptor, the Kernal Switch and the C64, refer to document number 128-6-04-00 (Wiring).

The Assembly of the Kernal Adaptor might require de-soldering the Kernal ROM U4 and installing a socket.

Trouble shooting

In case the C64 does not start properly, make sure, that the Kernal Adaptor is inserted properly into the socket and the EPROM is properly programmed. At least the first Kernal has to be programmed. The Kernal Switch should sit firmly on the keyboard connector and do not make electrical contact with any component leads of the C64 mainboard.

The Atmega328P has to be programmed with either the production file or the *.hex and the fuses have to be set properly (refer to document 128-6-05-00: Programming Guide).

Also, it is important to open or close the configuration solder bridge CP1 on the module to determine between a short and a long board. Form short boards, the solder bridge has to be closed, the BASIC has to be in the first 8k of the EPROM and a Kernal (original recommended) has to be in the 2nd 8k of the EPROM.

In case the Kernals do not switch in the sequence as they were programmed into the EPROM, most likely, the wiring between the Kernal Switch and the Kernal Adapter is wrong (refer to document 128-6-04-00: Wiring)

In case it is not working at all, remove the cable between the Kernal Switch and the Kernal Adaptor and set jumpers. Set all three jumpers (A13, A14, A15) for a long board and the jumpers A14 and A15 for a short board. In case it is working now, the Kernal Switch is selecting the wrong Kernal (maybe an empty 8k slot). Again, check the cable, measure the pins A13, A14 and A15 on the J4 with a multimeter. Keep in mind, that the first Kernal for a short board is 001_{BIN} and for a long board it is 000_{BIN}. A 0 here is represented by a low voltage (<0.7V) and a 1 is represented by a HIGH voltage (>4V).

If the problem is not solved, checking the solder joints is required. To see, if the software is running on the micro controller, a Serial Cable and a USB/Serial Adaptor plus the Arduino software (Tools → Serial Monitor, set to 9600 baud) might help.

After power up, the software should send messages via the serial cable. The RESTORE key has to be detected and reported (after holding it down) and a number key will be reported too.

Make sure, that the C64 power supply and the PC are connected and that the cables do not for a big loop. This might prevent a proper function. The serial connection is only for programming (in some cases) and for debugging, so it is not a problem, if a ground loop causes problems. It was experienced, that with a big ground loop (a couple of square meters) the C64 did not always start properly.

Keyboard Monitoring

The columns 1-4 and 7 as well as the rows 0 and 3 are connected to IO-pins of the micro controller. The C64 sends a scan bit to the columns, which are HIGH on default. The scan bit is LOW and it is shifted through the columns, one at a time. The rows are read back by the C64. A LOW signal on one or more row bits indicates a pressed key.

The following keyboard scan information can be obtained by the microcontroller:

	Column				
	7	4	3	2	1
Row 0	"1"	"9"	"7"	"5"	"3"
Row 3	"2"	"0"	"8"	"6"	"4"

It is obvious that only the numerals are being monitored. Further the RESTORE key is connected to the microcontroller.

Programming model

Pin	GPIO	Arduino	Function	Configuration	
30	PD0	D0	RxD	Input	Serial Receive
31	PD1	D1	TxD	Output	Serial Transmit
32	PD2	D2	Row0	Input, weak pull-up	Active LOW, INT0
1	PD3	D3	Row3	Input, weak pull-up	Active LOW, INT1
2	PD4	D4	KSW_A13	Output	Kernal Switch A13
9	PD5	D5	KSW_A14	Output	Kernal Switch A14
10	PD6	D6	KSW_A15	Output	Kernal Switch A15
11	PD7	D7	C64RES	Output	Active HIGH
23	PC0	A0	COL1	Input, weak pull-up	Keyboard column 1
24	PC1	A1	COL2	Input, weak pull-up	Keyboard column 2
25	PC2	A2	COL3	Input, weak pull-up	Keyboard column 3
26	PC3	A3	COL4	Input, weak pull-up	Keyboard column 4
27	PC4	A4	COL7	Input, weak pull-up	Keyboard column 7
28	PC5	A5	$\overline{\text{RESTORE}}$	Input, weak pull-up	RESTORE-Key, active LOW
12	PB0	D8	$\overline{\text{SHORT\_BRD}}$	Input	Short Board, active LOW
13	PB1	D9	RS1	TBD	Reserve IO Pin#1
14	PB2	D10	RS2	TBD	Reserve IO Pin#2

Connectors

J1 - Keyboard connector to mainboard

Bottom Entry receptacle (1x20p, pitch 2.54mm) – Harwin M20-7862042

Pin	Signal	Pin	Signal
1	GND	11	ROW1 (PB1)
2	No pin	12	ROW0 (PB0)
3	$\overline{\text{RESTORE}}$	13	COL0 (PA0)
4	+5V	14	COL6 (PA6)
5	ROW3 (PB3)	15	COL5 (PA5)
6	ROW6 (PB6)	16	COL4 (PA4)
7	ROW5 (PB5)	17	COL3 (PA3)
8	ROW4 (PB4)	18	COL2 (PA2)
9	ROW7 (PB7)	19	COL1 (PA1)
10	ROW2 (PB2)	20	COL7 (PA7)

J2 – In System Programming

2x3 box pin header (2.54mm pitch). This connector is used for the initial in-system programming of the ATmega238p (IC1). 89

Pin	Signal	Pin	Signal
1	MISO	2	+5V
3	SCK	4	MOSI
5	$\overline{\text{RESET}}$ (IC1)	6	GND

J3 – Serial/Debug

1x5 pin header (2.54mm pitch). In Arduino mode (after programming the Arduino boot loader), a USB/serial converter can be used to transfer the compiled Arduino sketches and for debugging with the serial monitor.

Pin	Signal	USB/Serial converter
1	GND	GND
2	+5V	+5V
3	TxD (output)	RX
4	RxD (input)	TX
5	DTR (input)	DTR

J4 – IO-Connector

1x6 pin header (2.54mm pitch)

This connector outputs the control signals of this board. It is for being connected to the Kernal and/or keyboard adapter. It also provides two reserved IO-Pins for later use.

Pin	Signal	Function
1	KSW_A13	Kernal Switch/Adapter A13
2	KSW_A14	Kernal Switch/Adapter A14
3	KSW_A15	Kernal Switch/Adapter A15

Pin	Signal	Function
4	$\overline{\text{C64\_RESET}}$	RESET signal for the C64 (to be connected to a RESET point on the mainboard
5	RESIO1	Reserved IO
6	RESIO2	Reserved IO

J5 - Keyboard connector

Pin header (1x20p, pitch 2.54mm) – Pin 2 clipped off (no pin)

Pin	Signal	Pin	Signal
1	GND	11	ROW1
2	No pin	12	ROW0
3	$\overline{\text{RESTORE}}$	13	COL0
4	+5V	14	COL6
5	ROW3	15	COL5
6	ROW6	16	COL4
7	ROW5	17	COL3
8	ROW4	18	COL2
9	ROW7	19	COL1
10	ROW2	20	COL7

Documents

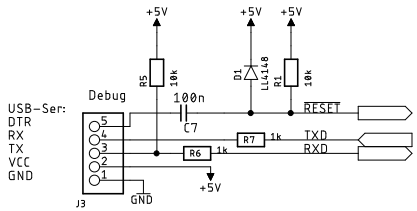
Document	Document Number
Disclaimer	-
Module Description (this document)	128-6-01-**
Schematic	128-1-01-**
PCB prints	128-2-01-**
Functional Description	128-6-02-**
Software Description	128-6-03-**
Wiring	128-6-04-**
Programming Guide	128-6-05-**
Testing	128-6-06-**
Bill of Material	128-5-01-**.*

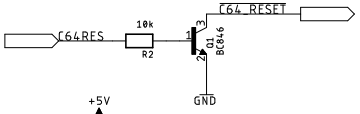
**: depends on revision.

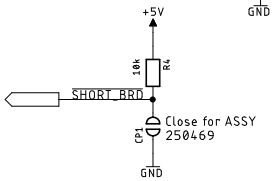
Revision History

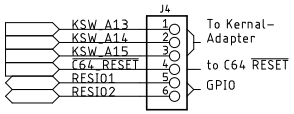
Rev. 0

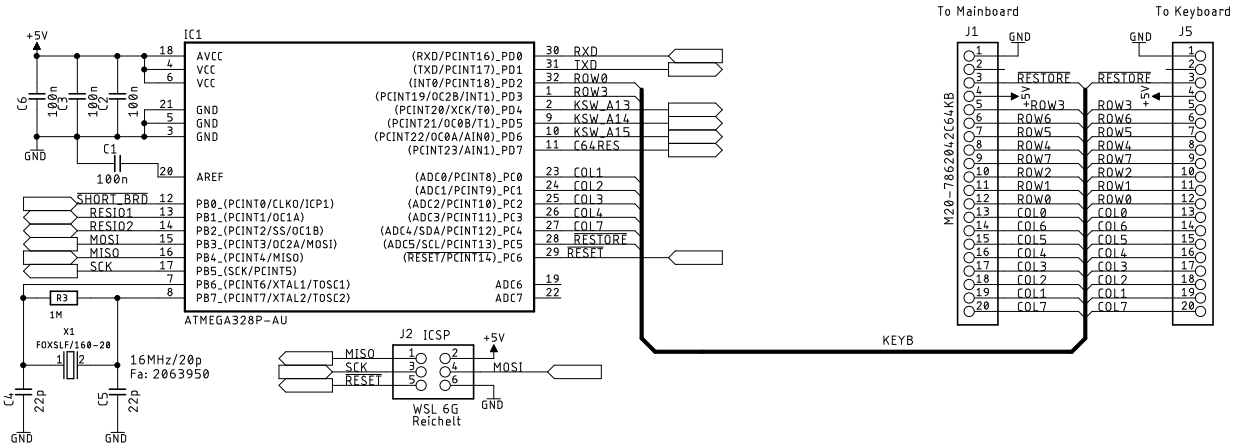
- Prototype (fully functional)











	Column				
	7	4	3	2	1
Row 0	"1"	"9"	"7"	"5"	"3"
Row 3	"2"	"0"	"8"	"6"	"4"

C64 applies LOW pulses to each column and reads back the rows.

Title:	C64 Keyboard Controlled Kernal Switch	Doc.-No.:	128-1-01-00
		Draft.:	Sven Petersen
Date:	15.06.2019 14:35	Rev.: 0	Page 1/1
File:	C64_Kernal_Switch		
			A3

Sven Petersen 2019	Doc.-No.: 128-2-01-00	
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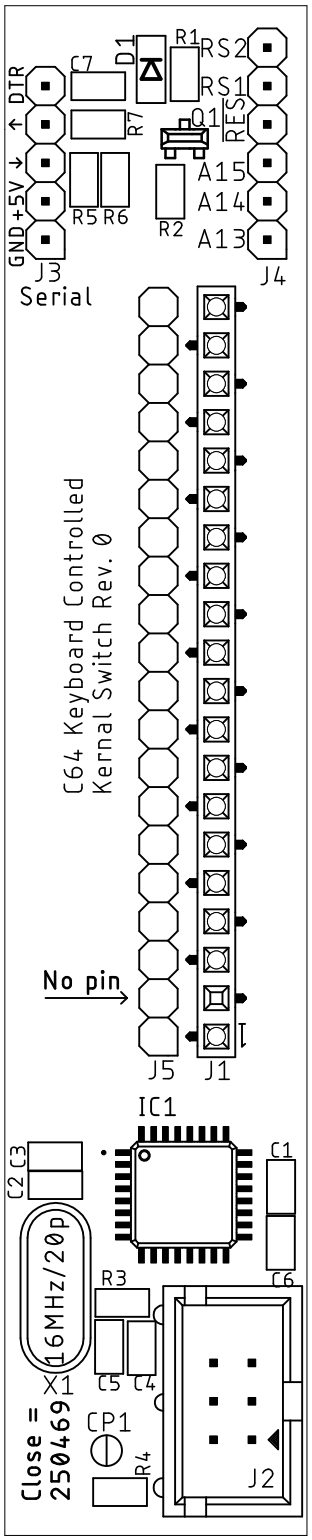
C64_Kernal_Switch		
15.06.2019 14:35		Rev.: 0
placement component side		



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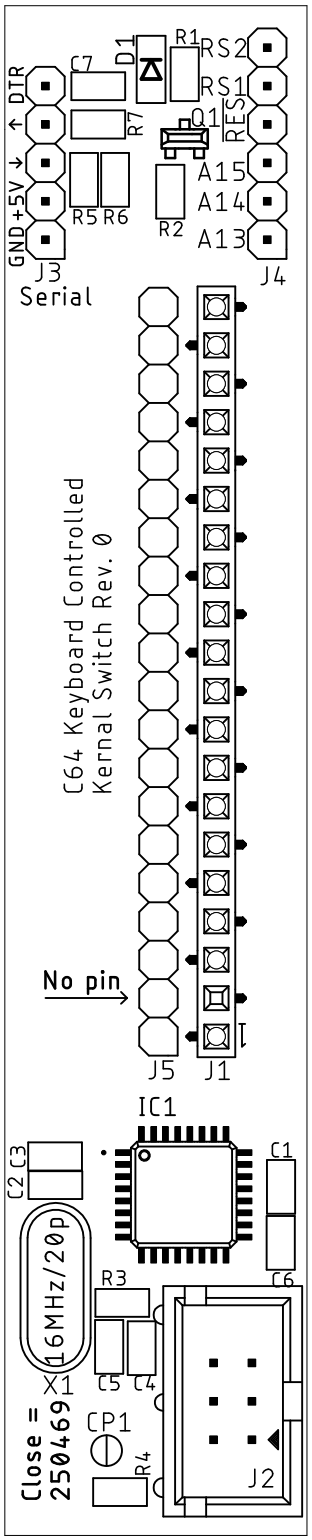

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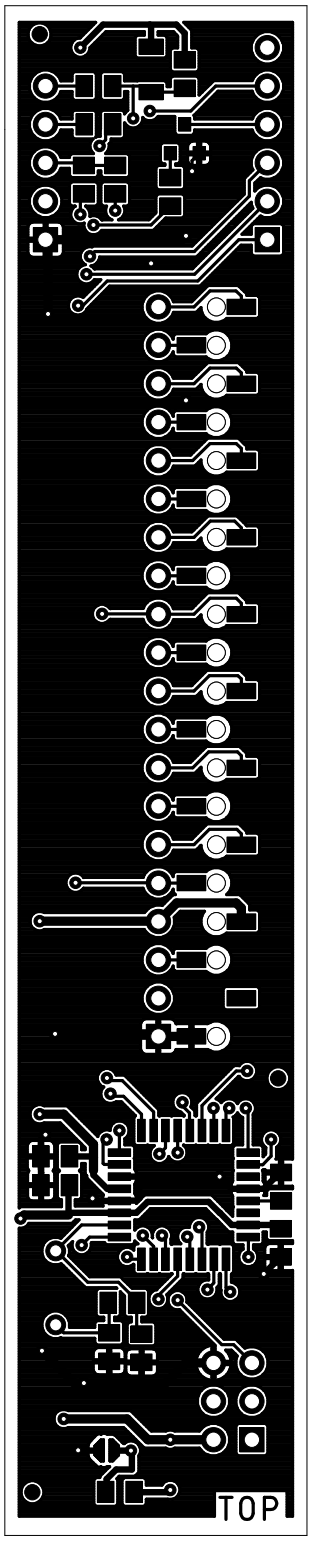

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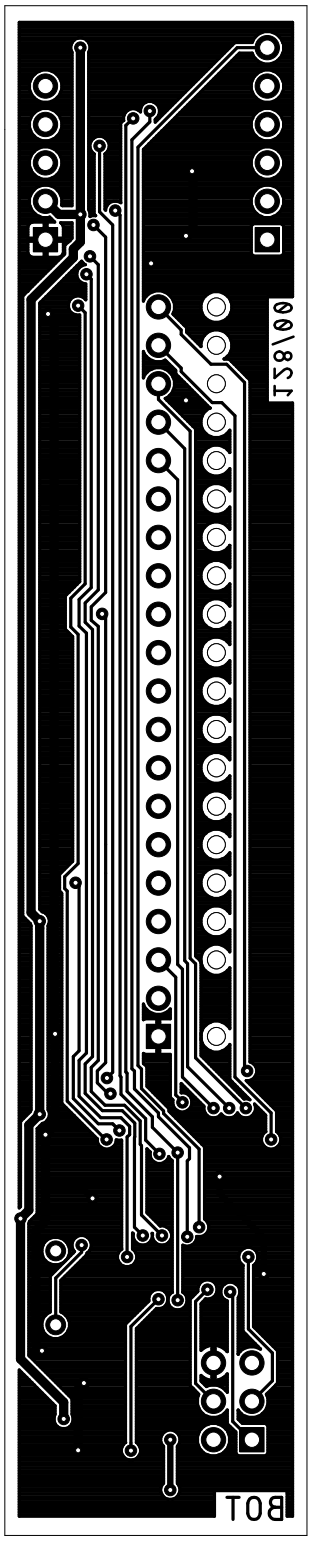

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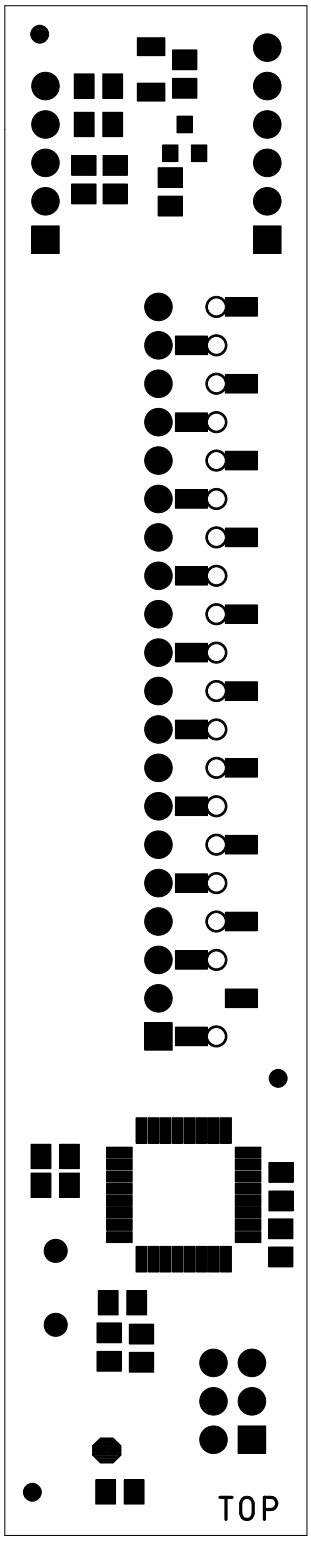
stopmask component side		



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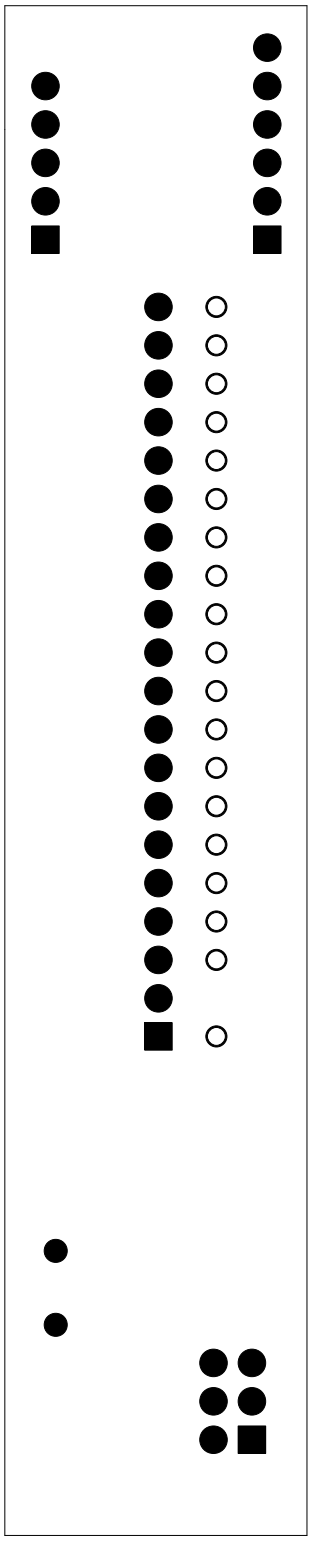

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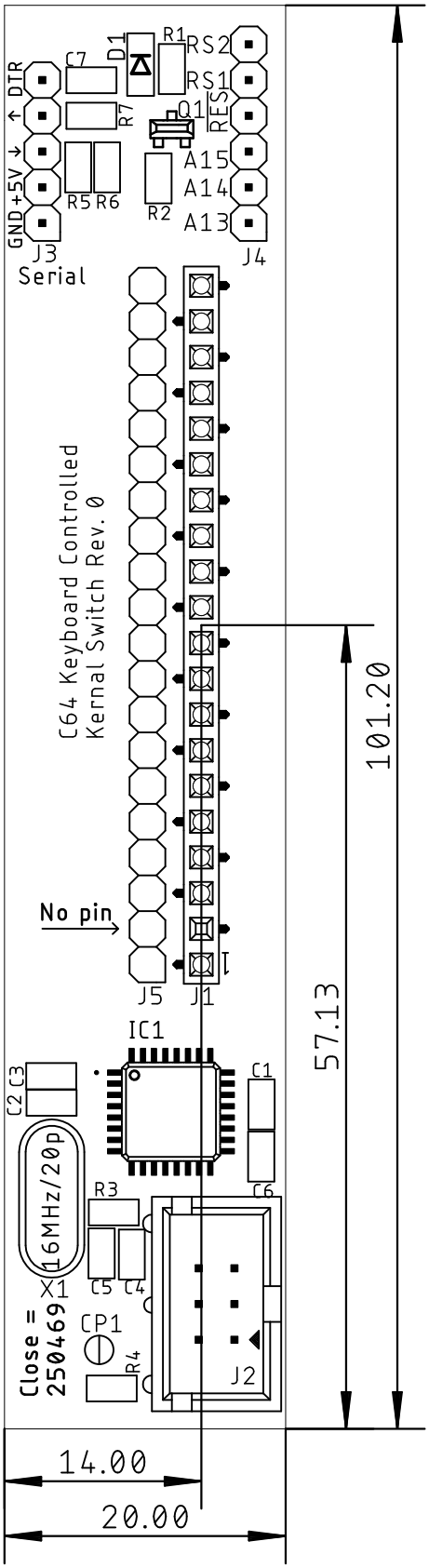
placement component side measures		



C64 Keyboard Controlled Kernal Switch Rev. 0

Functional Description

IC1 is an ATmega328P processor and it provides the functionality of an Arduino Uno. X1 is the 16MHz quartz and forms the quartz oscillator together with C4, C5 and R3. J2 is the connector for in-system programming of IC1. It is required at least once for burning the Arduino bootloader.

A serial interface for debugging is provided on J3. This interface has a TTL-level serial signals. To connect it to a PC, a USB/serial converter board is required. Once the bootloader is programmed into IC1, the serial interface can serve to transfer a compiled Arduino sketch to the Kernal Switch. In case this serial interface is not desired, J3, C7, D1and R7 can stay not populated.

The Kernal Switch has to distinguish between long boards and short boards. The reason is, that in a short board, the BASIC resides in the lowest 8k of the EPROM. A[15..13] (of the EPROM) ranges from 001_{BIN} to111_{BIN}. For a long board, all 8k memory slots can serve as a Kernal, so A[15..13] range from 000_{BIN} to 111_{BIN}. The solder bridge CP1 serves for setting the board type. In case it is open, a long board is configured. To configure a short board, it has to be closed by soldering.

The transistor Q1 serves for resetting the C64 and provides the required open collector output. A HIGH level on C64RES will pull the output $\overline{\text{C64\_RESET}}$ LOW, which then resets the C64.

J4 is the pin header, which provides the signals for selecting the Kernal (KSW_A13 .. KSW_A15), for resetting the C64 ($\overline{\text{C64\_RESET}}$) and two GPIO-pins (RESIO1 and RESIO2), which are not assigned to a purpose, yet.

J1 is a bottom entry receptacle, the pins of the keyboard connector are inserted through holes in the PCB into this connector from below. All keyboard signals are connected here. J1 provides the supply voltage (+5V) for the circuit on the Kernal switch.

J5 is the pin header for connecting the keyboard. All (keyboard) signals from J1 are connected to the same pin on J5.

Only the required scan signals are connected to IC1. That is column 1, 2, 3, 4 and 7, as well as row 0 and 3. The row signals are pulled LOW in case a key in the row is being pressed. These row signals are connected to the two external interrupt pins (INT0 and INT1) of IC1. The key scan signals have to be configured as “input with weak pull-up resistor”, since the TTL logic of the C64 interprets an open input as a HIGH input, while it is an illegal state for the MOS logic of IC1.

C64 Keyboard Controlled Kernal Switch Rev. 0

Software Description

The software is programmed as an Arduino sketch. The purpose for this is to provide the user a way to modify the software for the personal requirements and to upload it via the serial port J3. This requires a cable and USB/serial converter, which will be described in another document.

The name of the Arduino sketch is *c64ksksw.ino*

The setup routine is initializing the pin modes than reads the configuration jumper to determine, if a short board or a long board is detected. It reads the last selected Kernal number from the EEPROM of the microcontroller. If this is in range, the Kernal will be selected with the output bits KSW_A13 … KSW_K15. In case, the value provided by the EEPROM is out of range, the first possible 8k memory slot will be selected as a Kernal (depending on short board or long board).

The C64 scans the keyboard by setting the column bits and reading back the row bits. Each of the 8 columns (the vertical structures of the keyboard matrix) is connected to one side of eight keyboard switches. Eight rows (the horizontal structures of the keyboard matrix). While figuring out, which key is pressed, the C64 sets the columns LOW, one by one. Then it ready back the row (as a byte, one bit per row). A bit value 0 (LOW) indicates exactly the key, which is pressed. In case there is just one key pressed, all other row bits are 1 (HIGH).

There are also some other scan activities, which have to be filtered out. E.g. to determine, if a key is pressed (at all), all columns are set to LOW.

In case there is not proper Kernal in the selected memory slot, the C64 crashes (only a software thing, it will not harm the computer). A crashed C64 will not provide any keyboard scanning activities. The software can detect this state and the Kernal Switch will recover to the first Kernal. This is done by reading the column information. In case a value other than "HIGH" will occur in any of the bits before a timeout period elapses, the Kernal is considered to be working.

The two relevant row signals (ROW0 and ROW3) are connected to the two hardware interrupts. Pressing one of the number keys will generate an interrupt. So, there are two interrupt routines. Those will read the column data (the complete PORT C of the processor) and mask the relevant bits (0..4) if those are neither 11111_{BIN} nor 00000_{BIN}, a number key is detected and two flags are set and the column data is preserved, indicating the main loop, that something happened.

The main loop is first trying to find any keyboard activity. Once found, it will not be searched anymore.

Next, the state of the RESTORE key is read. In case the bit is LOW, the restore key is pressed. A count down is started. If the RESTORE key is held for a couple of seconds, the C64 will be reset. The reset signal is issued for two seconds. The keyboard scan timeout is initialized again.

In case the Interrupt Service Routines (ISR) attached to the row bits is informing the main loop, that a number key was pressed, it starts to decode the column information are determines the pressed key. The first key, that is found, will be assumed to be the choice of the user. Multiple keys are not processed.

In case the number is in range, the Kernal number is written to the EEPROM, then the Kernal is selected by setting KSW_A13 … KSW_A15 and resetting the C64. Finally, the main loop waits for 1000µSec. The loop time is not calibrated.

The initial keyboard scan detection might conflict with some cartridges, which do not provide keyboard scanning. One is the dead test cartridge. The Kernal switch can be "deactivated" for such a cartridge, either by pressing RESTORE 0 or by modifying the sketch. (the first the recommended way).

```
/* Configuration */

const bool recover_empty = true;      //enable recover to Kernal one, in
case an empty/not working kernal was selected

const int  NumKernal = 8;             //This is the highest valid Kernal
number
```

For this purpose, the constant `recover_empty` has to be set to false and the constant `NumKernal` has to be set to the number of Kernals programmed.

C64 Keyboard Controlled Kernal Switch Rev. 0

Wiring

Connections

There is one required connection, the Control Signals Cable. The Serial Cable to the USB/Serial-converter is optional and only required, for uploading an Arduino sketch to the Kernal Switch.

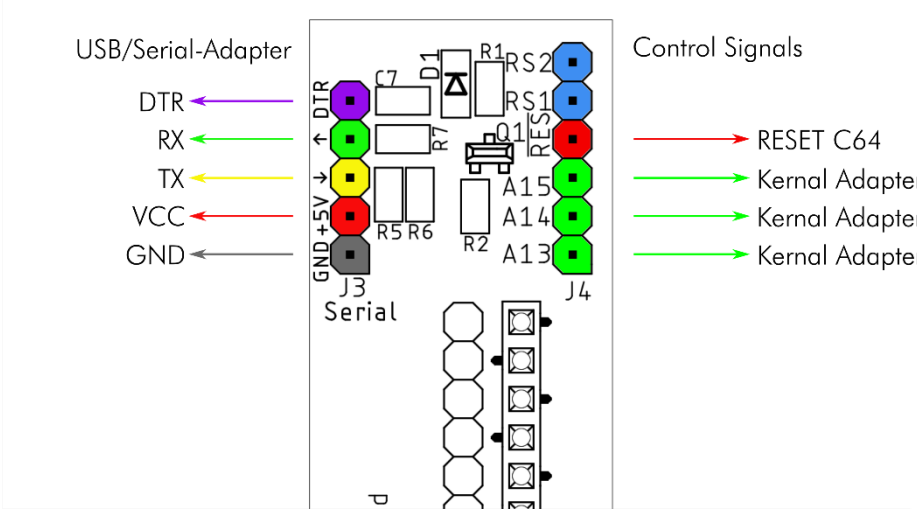


Figure 1: Connectors J3 and J4 of the Keyboard Controlled Kernal Switch

Control Signal Cable

A wire connection between the keyboard controlled Kernal switch and the Kernal adapter is required to select the desired Kernal. Further on, the module has to reset the C64 after changing to that Kernal.

A recommended connector type is the wide spread Dupont connector. The contacts need to be crimped to the cable, which might not be possible for everybody.

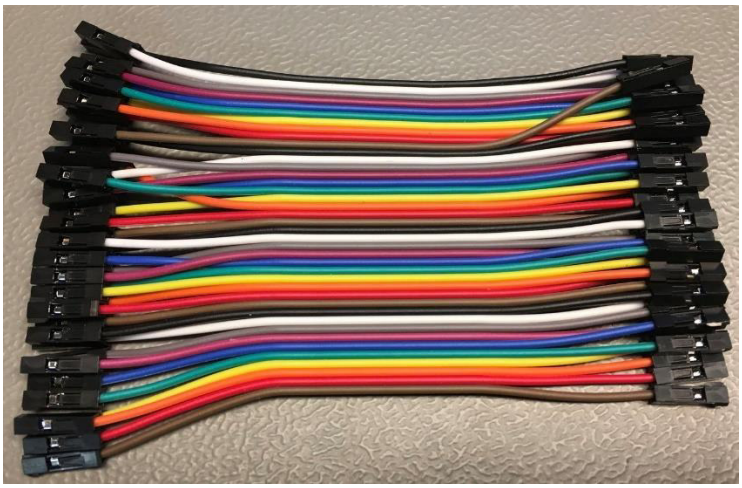


Figure 2: Prefabricated Dupont Cable

The prefabricated Dupont cables (female – female) from Ebay might be the 2nd best solution. For the short board, 30cm cables are required, for the long board, 10cm cables are enough.

Those prefabricated Dupont cables come as ribbon cables (usually 40 poles), the Dupont contacts are single ones. The desired amount of wires can just be teared off the ribbon cable

An alternative may be receptacles, which fit on pin headers with the cables soldered to them. The next possible solution might be leaving the pin headers on Kernal switch and Kernal adapter not populated and solder in the cables directly.

Now, a pin header (one pin) on the RESET signal of the C64 is required to be soldered. This signal can be found near the user port. Looking from the port side, it is the 3rd contact from the left on the top layer. It is not good to solder the pin directly at the contact, but on a solder pad or via near it.

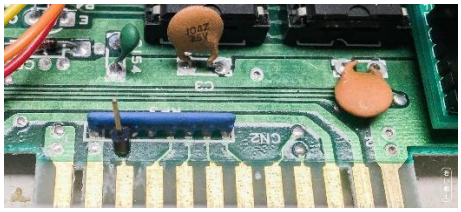


Figure 3: Reset Contact ASSY 250425 (identical to ASSY 250407)

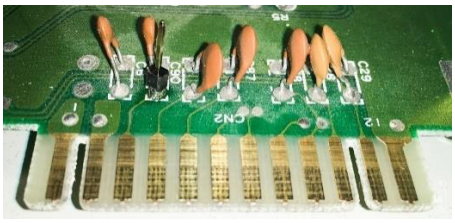


Figure 4: Reset Contact ASSY 250469 (front pin of C90)

The required connections are:

Kernal Switch J4	Kernal Adaptor JP1	C64 Mainboard
A13	A13	-
A14	A14	-
A15	A15	-
$\overline{\text{RES}}$	-	RESET Pin (Figure 3 & Figure 4)

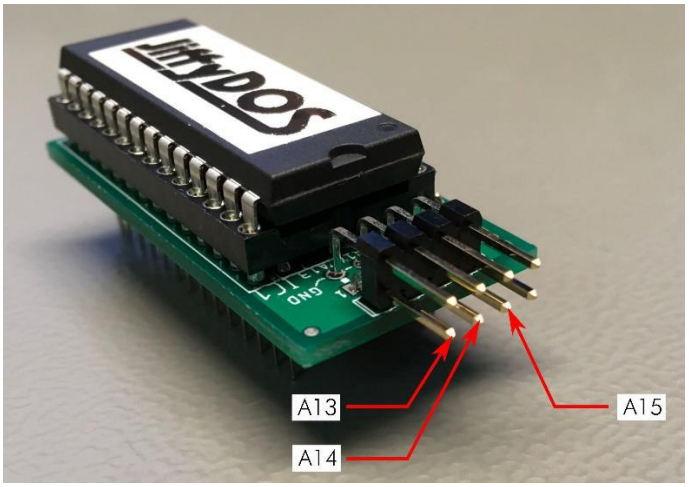


Figure 5: Connector of the Kernal Adapter

Although the long boards and the short board require different Kernal adapters, both connectors are the same. This is shown in Figure 5.

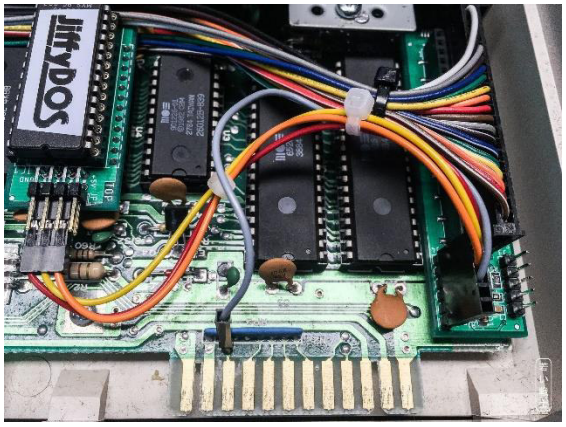


Figure 6: Wiring of ASSY 250425

Figure 6 show the wiring of ASSY 250425 (ASSY 2502407 is similar). The grey cable is the reset signal, which is attached to the RESET pin header, that was installed previously.

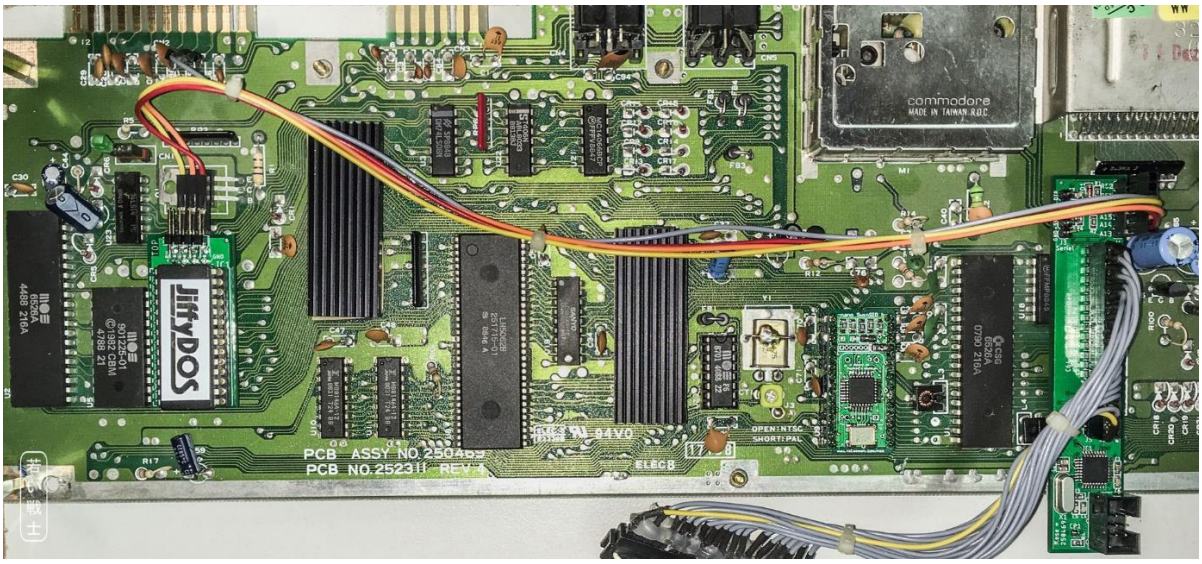


Figure 7: Wiring of ASSY 250469

Figure 7 shows the wiring of ASSY 250469 (the short board). Again, the grey cable is the RESET signal, which is attached to the previously soldered RESET pin near the user port.

Serial Cable

The Serial Cable can vary, depending on the used USB/Serial adapter board. An FT232 based adapter is recommended, which is widely used, provides +3.3V and 5V operation and driver software up to Windows 10.

The USB/Serial adaptor provides VCC (+5V) to the module. This is helpful while programming the microcontroller, but is not good, as long as the module is inserted in the C64 (and powered by it). In this case, the C64 would be powered via the USB interface of the computer. It does not destroy the C64. But for proper operation, the VCC should be interrupted or switched off. The serial interface can be helpful while debugging.

Again, the recommended connector type are Dupont connectors, with the alternative of using receptacles, which also fit on standard pin headers. Direct soldering is not recommended.

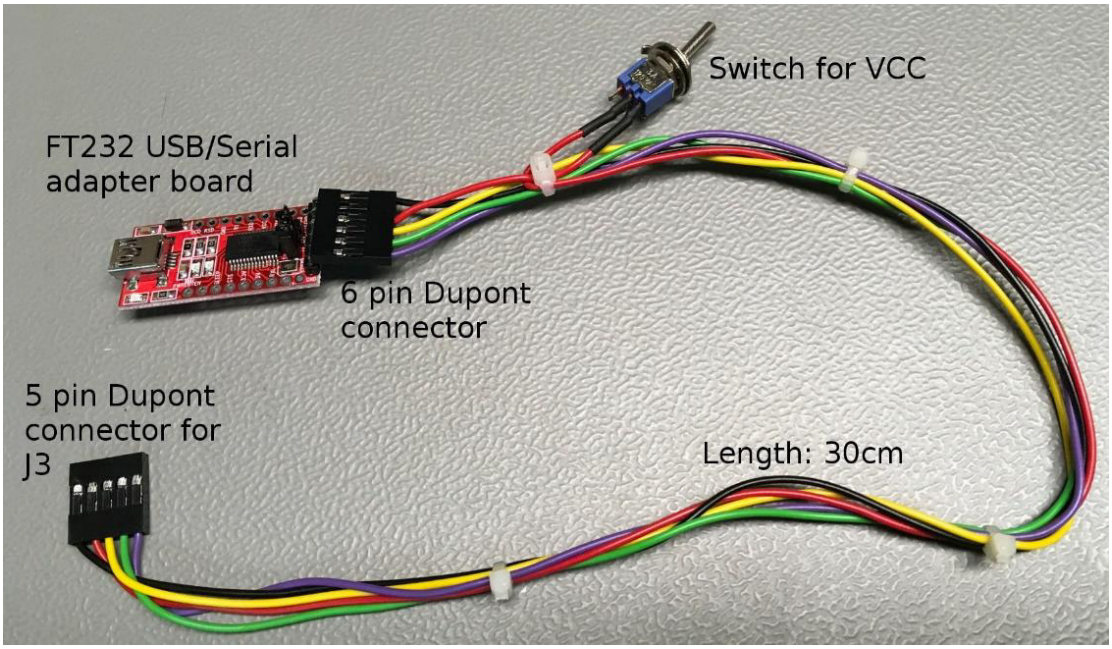


Figure 8: Serial Cable

Notice: While testing the Kernal Switch, the C64 sometimes did not start. As the culprit for this behavior, a ground loop was identified (via mains → PC → USB → Adapter → serial cable → Kernal Switch → C64 → C64 Power Supply → mains). After interrupting the ground loop, these problems did not occur anymore.

C64 Keyboard Controlled Kernal Switch Rev. 0

Programming Guide

Introduction

The microcontroller on the Kernal switch has to be programmed to function properly. There are several ways of transferring the program into IC1.

Since the program is based on the Arduino IDE, the program can be considered to consist of three parts:

- the Arduino Bootloader (optiboot_atmega328.hex)
- the fuses
- the compiled sketch (c64kbksw.ino)

The bootloader will enable the Arduino IDE to transfer (compiled) sketches via the serial cable into the ATmega328P microcontroller on the Kernal switch.

The fuses are the configuration of the ATmega328P. If those are not set properly, the Kernal switch will not work like desired.

The sketch is the source code of the program. It needs to be compiled and uploaded by the Arduino IDE (=*Integrated Development Environment*).

One pass programming

It is possible to transfer the bootloader, the compiled sketch and the fuses in one pass. That requires a suitable **programmer** (like the Atmel ICE, an SDK500 based programmer or another supported programming hardware). Further on, the **Atmel Studio** software is required. It is the IDE for writing software for Atmel controllers and programming the chips.

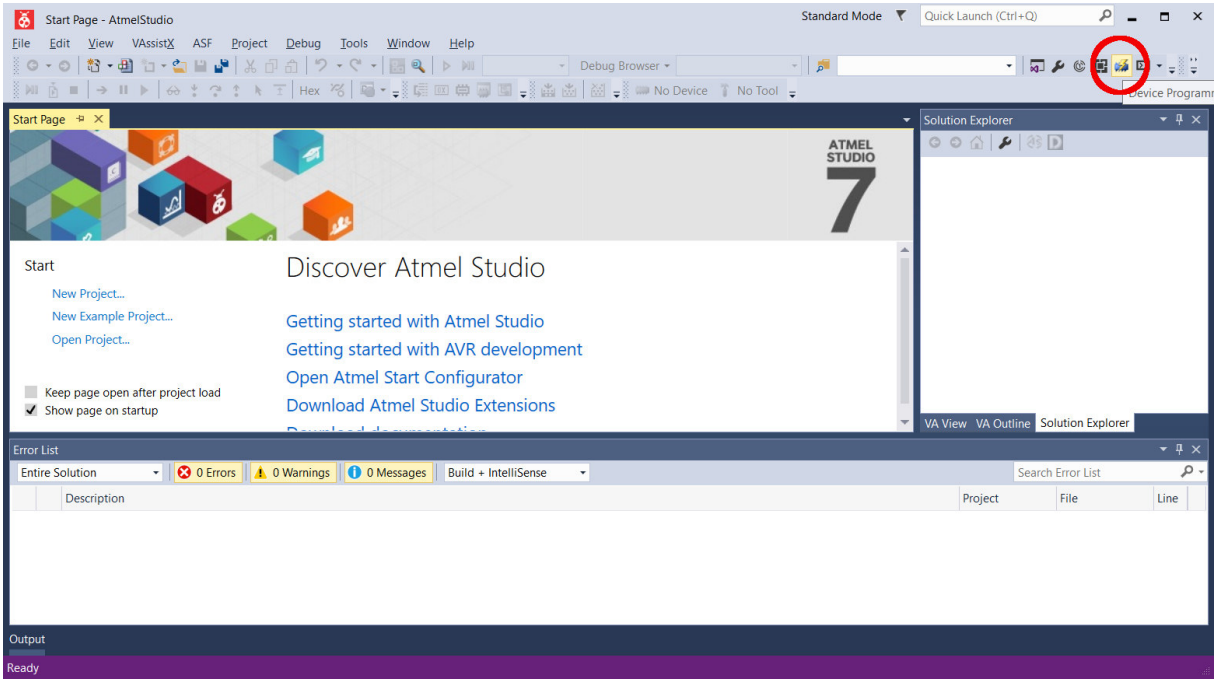


Figure 1: Atmel Studio IDE

The programming data is c64kbksw_v0_0.elf (or a later version). It was read out from an already programmed Kernal switch with a programmer and stored.

Step 1

Start the Atmel Studio IDE and select the Device Programming Tool as shown in Figure 1.

Step 2

Configure the tool (=the programmer), the device (Atmega328P), the interface (ISP = in-system programming) and click "Apply", like in Figure 2.

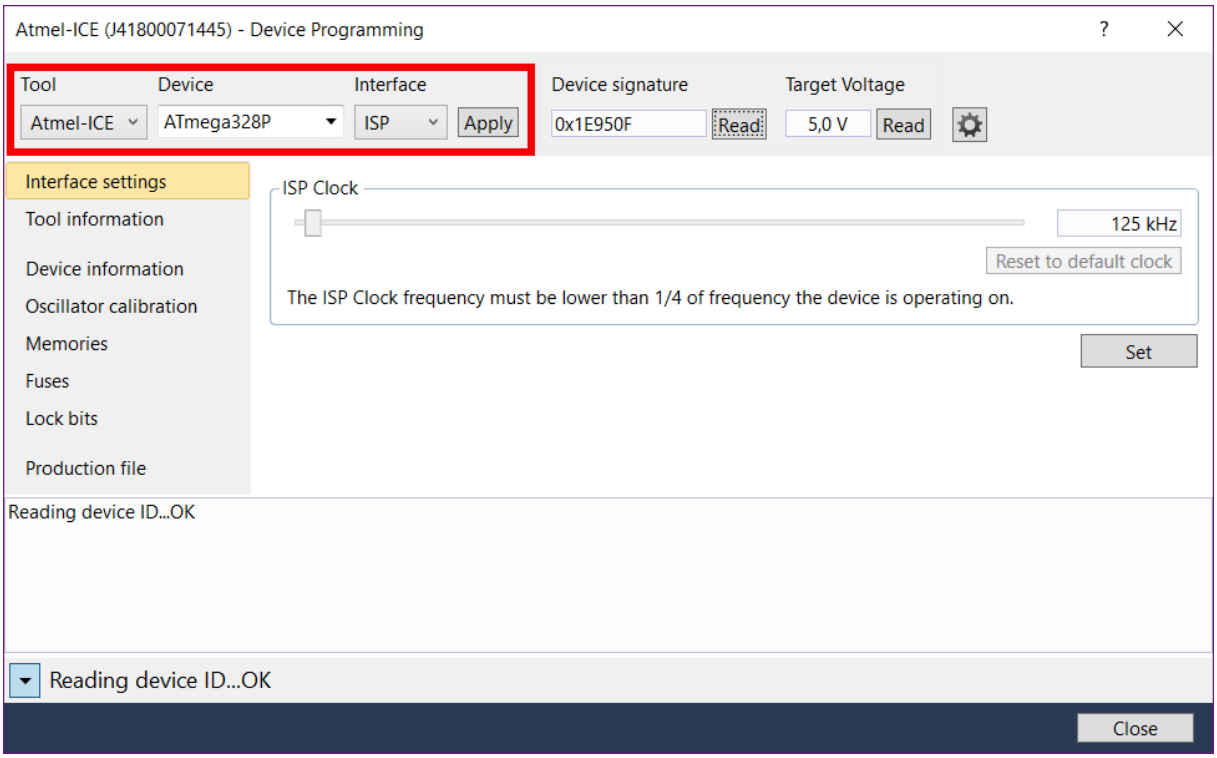


Figure 2: Device Programming

When you click "Read", the Device signature should be displayed and the Target Voltage should be shown (about 5V). In case, it does not, the module needs to be powered externally with 5V (connector J3). It can be done with the USB/Serial adaptor and the serial cable, or just a bench power supply.

Step 3

Click "Production File", then select the ELF production file (*c64kbksw_v0_0.elf* or later version) from the location, where you have stored it. Check "Flash" and "Fuses", also "Erase memory before programming" and "verify programmed content", like shown in Figure 3.

Now, click the "Program" button. The programming will start.

While the programming, the status is reported in the lower part of the window. This is marked yellow in Figure 4. Erasing, Programming Flash and Verifying, Programming fuses and Verifying should all be reported "OK".

Now, the program (bootloader and fuses included) is completely transferred to the ATmega328P. The module should be fully functional now. Since it contains the bootloader, the Kernal switch can be modified with the Arduino IDE and a serial cable.

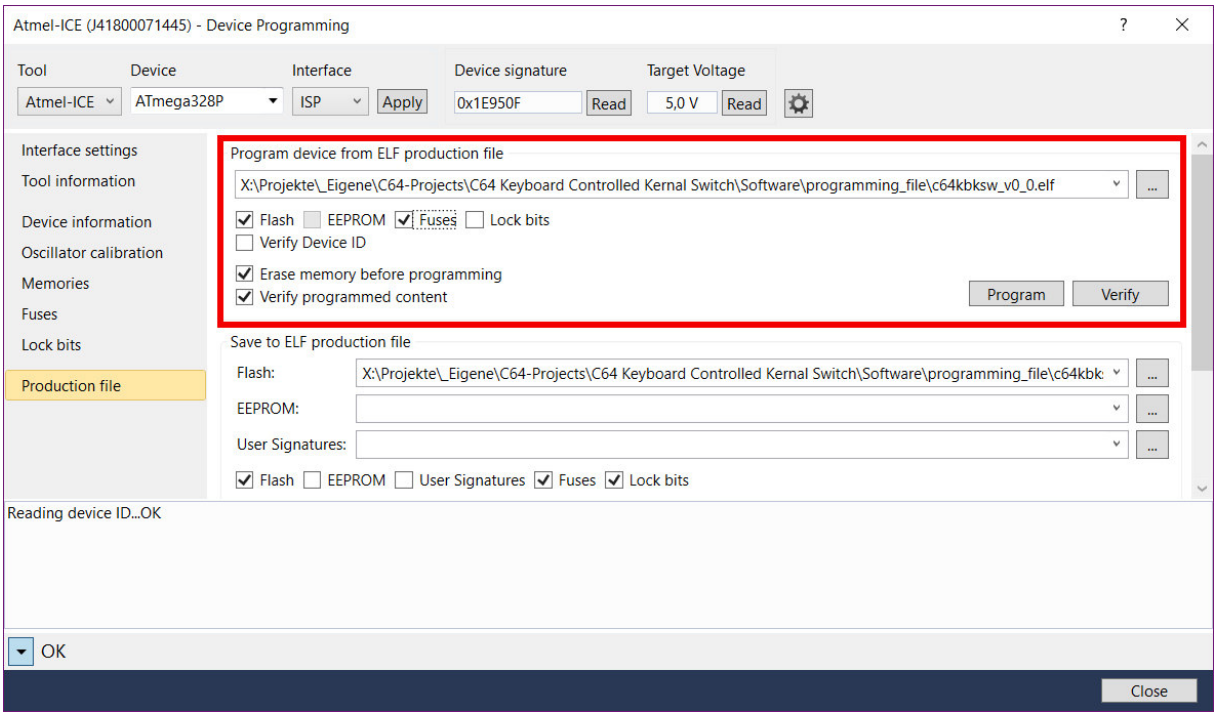


Figure 3: Production File settings

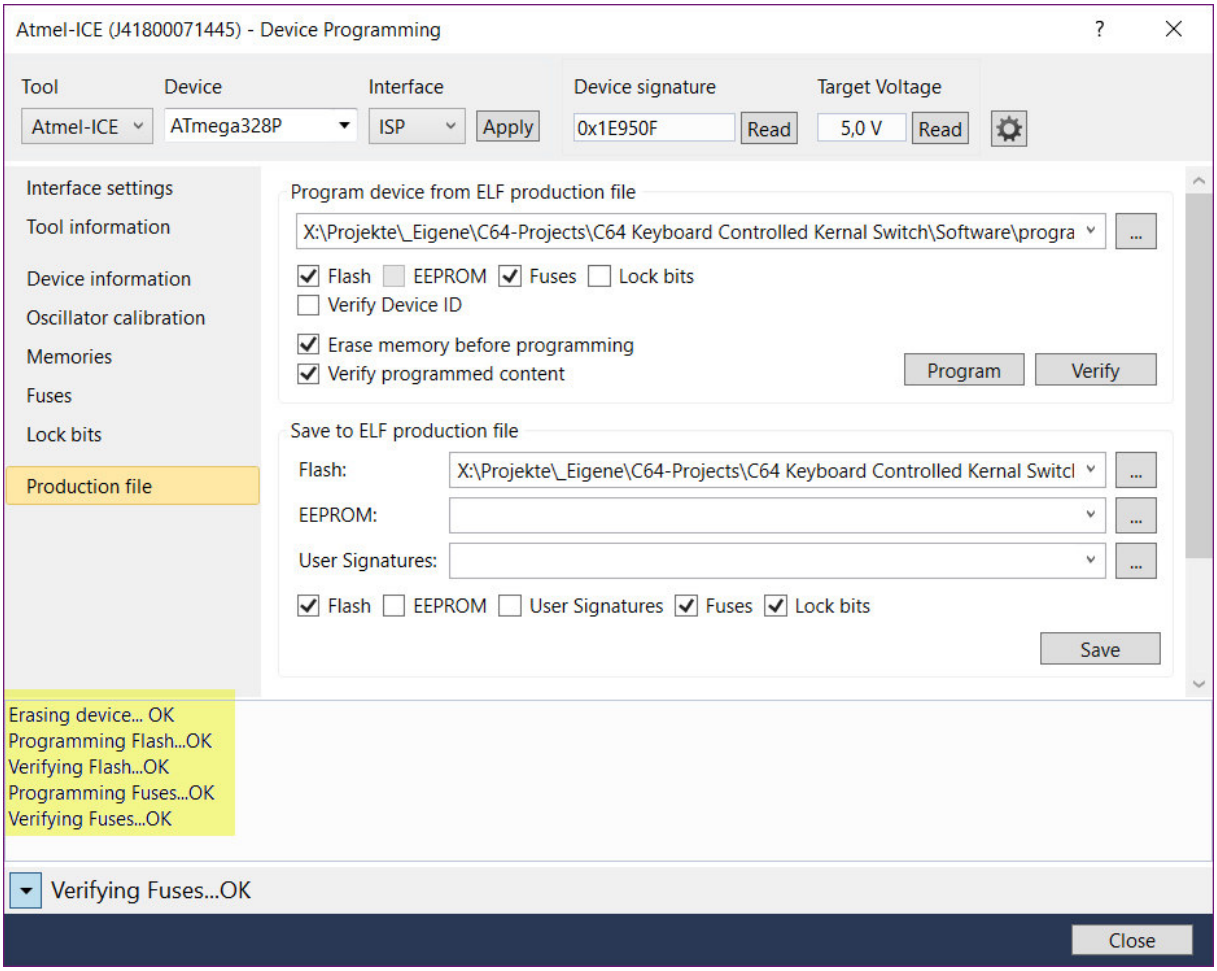


Figure 4: Programming the device

The fuses of the ATmega328P should be set like this:

- EXTENDED: 0xFD
- HIGH: 0xDE
- LOW: 0xFF

This can be checked with the Device Programming tool like in Figure 5.

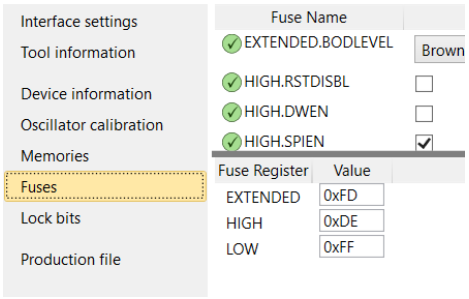


Figure 5: Fuses

One Pass Programming TL866

The ATmega328P can be programmed either with a TQFP32 adaptor or via the ICSP port. In both cases, the program (c64kbksw_v0_0.hex or a later version) has to loaded to the programming buffer (the format is intel HEX) and the fuses have to be set manually (see Figure 6). The file contains the bootloader and the compiled sketch. No further programming is required.

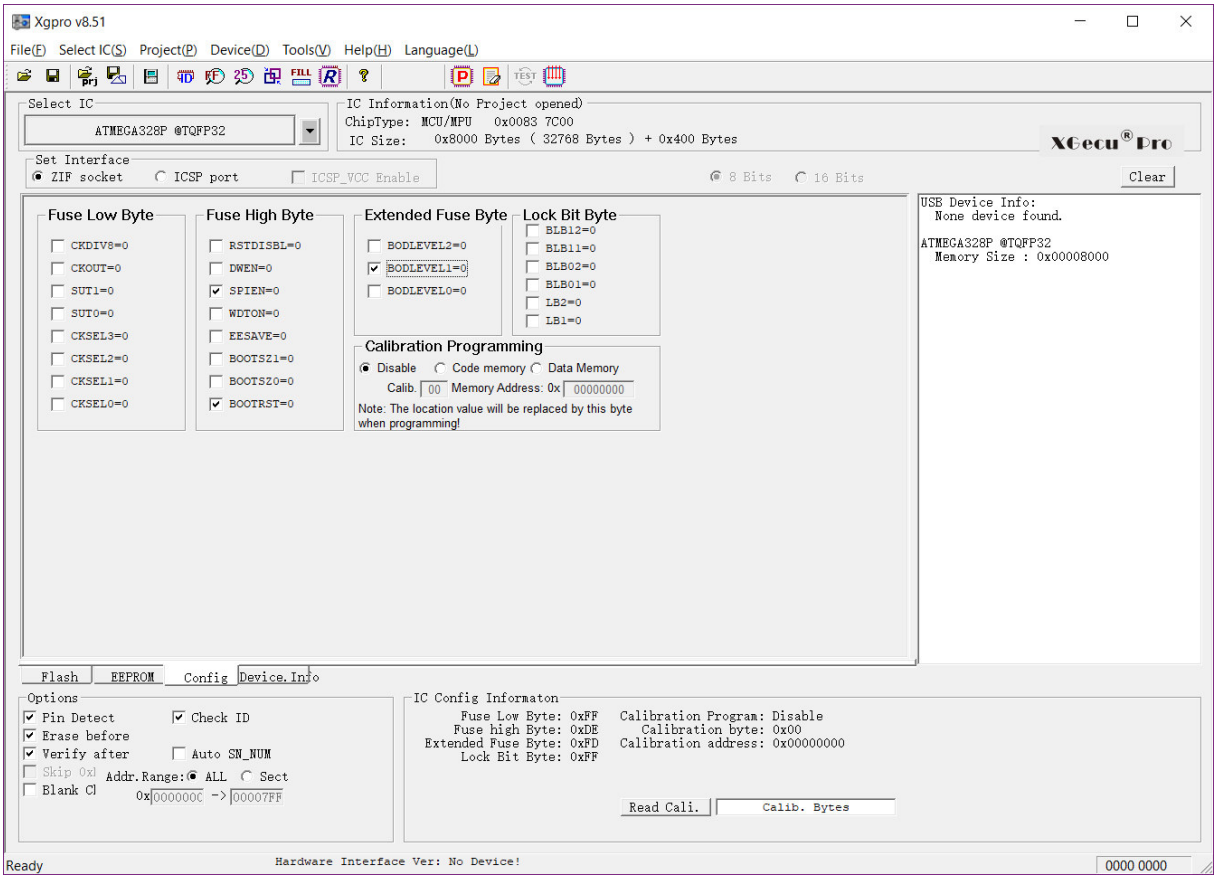


Figure 6: Correct setting of the fuses

This setting can be found in the “Config” tab.

Without a TQFP32 adaptor, the processor can be programmed in-system. The TL866II+ and the TL866A provide such an ICSP port. As a cable, a 6-wire Dupont cable will work (see Figure 9).

The connections should be made according to Figure 8.

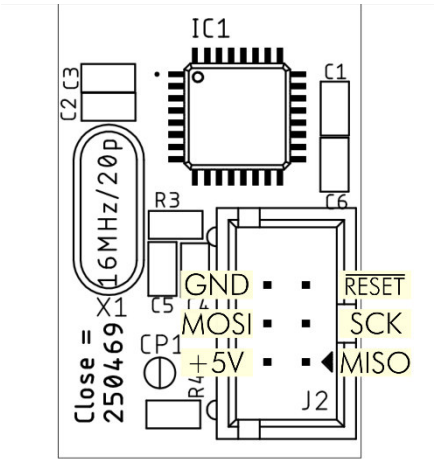


Figure 7: Pinout of the ICSP connector J2

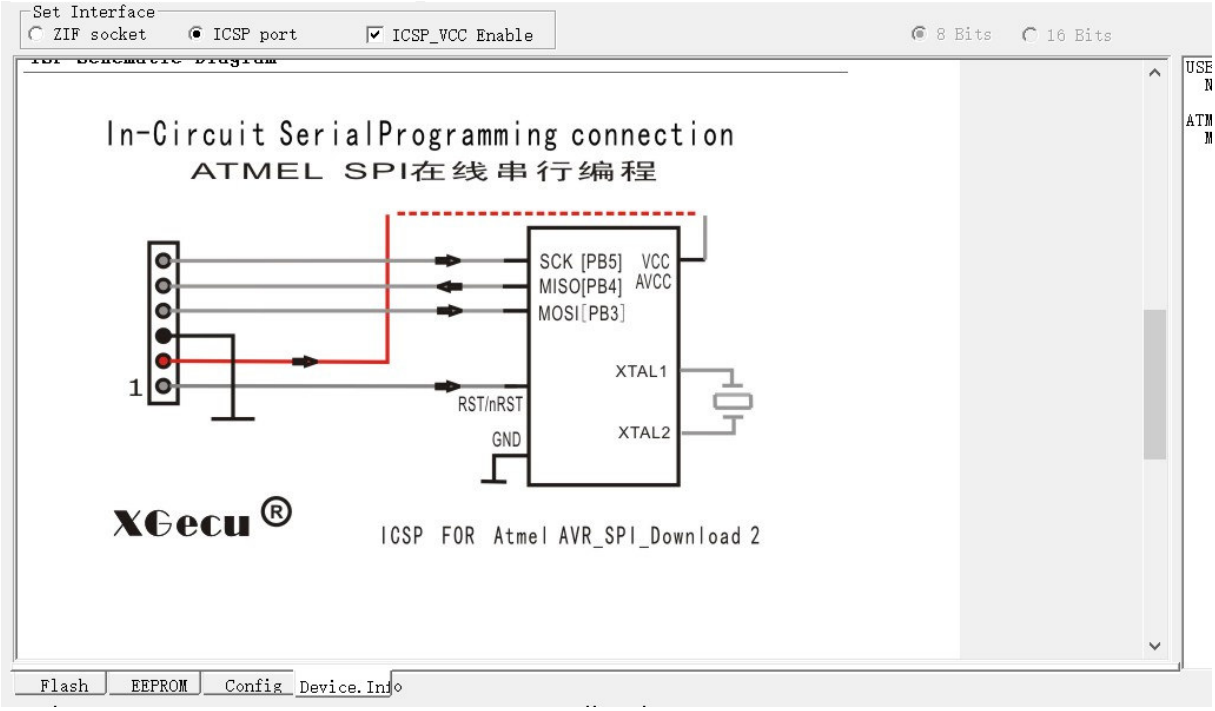


Figure 8: ICSP connection from TL866II+ to ATmega328P

The Dupont cable needs to be connected correctly, the connection has to be double checked to prevent harming the module or the programmer. In case, the repeated programming is intended, it might make sense to build a cable with a real 6x1 and 3x2 pin Dupont crimp housing (the 1pin crimp housings of the cable can be uninstalled).

When programming the controller, make sure, the code memory and the fuses are checked (Figure 10).

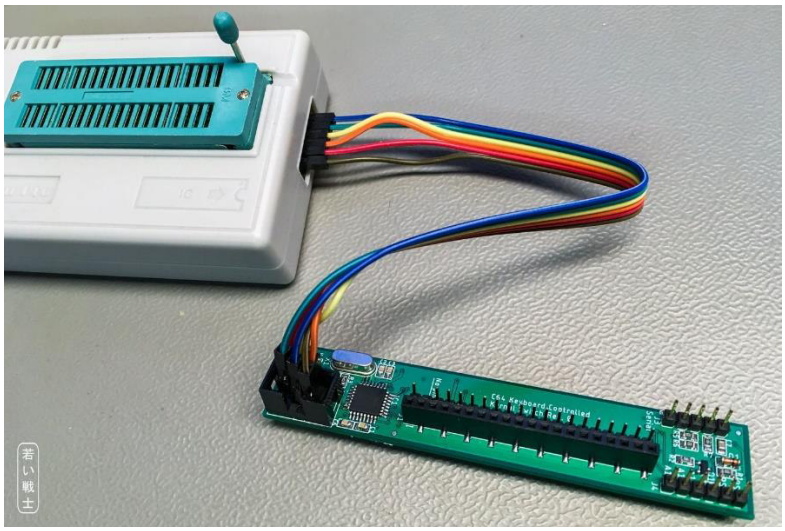


Figure 9: ICSP with a Dupont cable

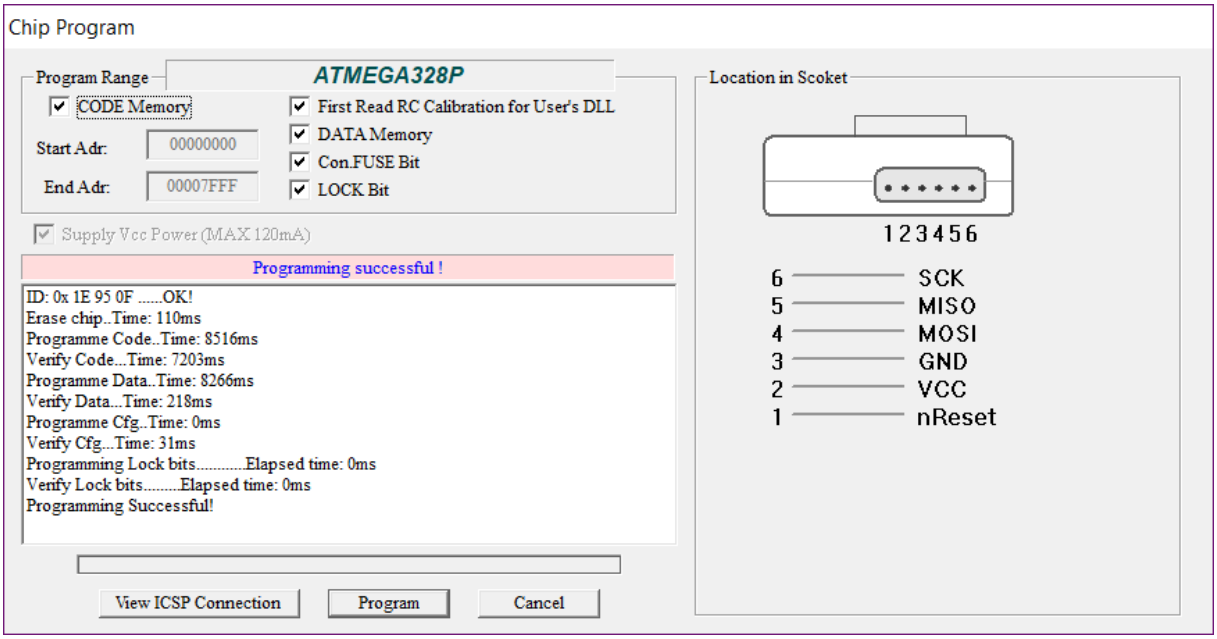


Figure 10: Programming the ATmega328P with the TL866II+

Programming the bootloader from the Arduino IDE

With a supported programmer or a programmer made from an Arduino Uno, the Arduino bootloader can be programmed into IC1. The fuses will be set correctly by the software.

The cheaper In-Circuit programmers for the Atmel processors usually mimic the STK500 development board. The functions described can be found in the Tools menu. Select the right programmer type, for STK500 you also have to set the right port (this is not the COM-Port provided by the USB/Serial adaptor). Once the Programmer and the port are set, connect the module to this programmer and click “Burn Bootloader” in the Tools menu of the Arduino software.

Instructions how to set up an Arduino Uno for programming the bootloader can be found by Google.

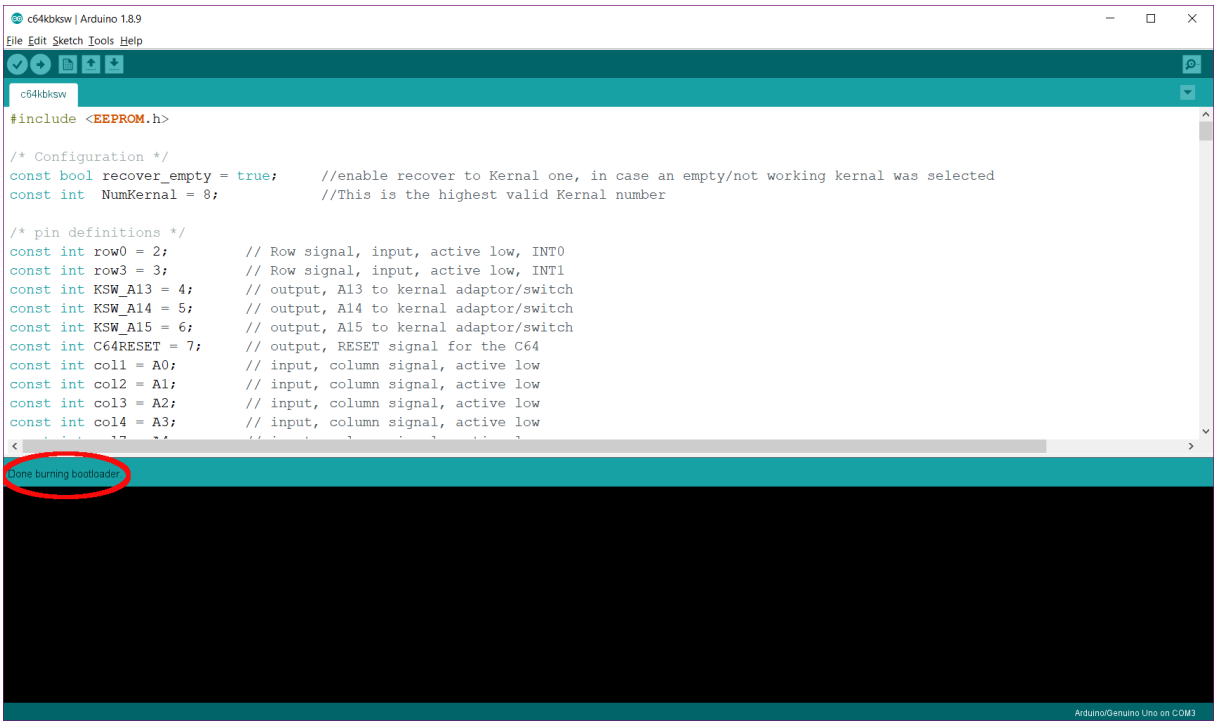


Figure 11: Burning the bootloader with the Arduino software

Note: the Atmel-ICE Programmer did not work properly for burning the bootloader from the Arduino software. If you own this programmer, you can program the bootloader wit the Atmel Studio software.

Programming the bootloader from Atmel Studio

The Arduino IDE software contains the programming (*.hex) file for the optiboot bootloader, which is used for Arduino Uno etc.

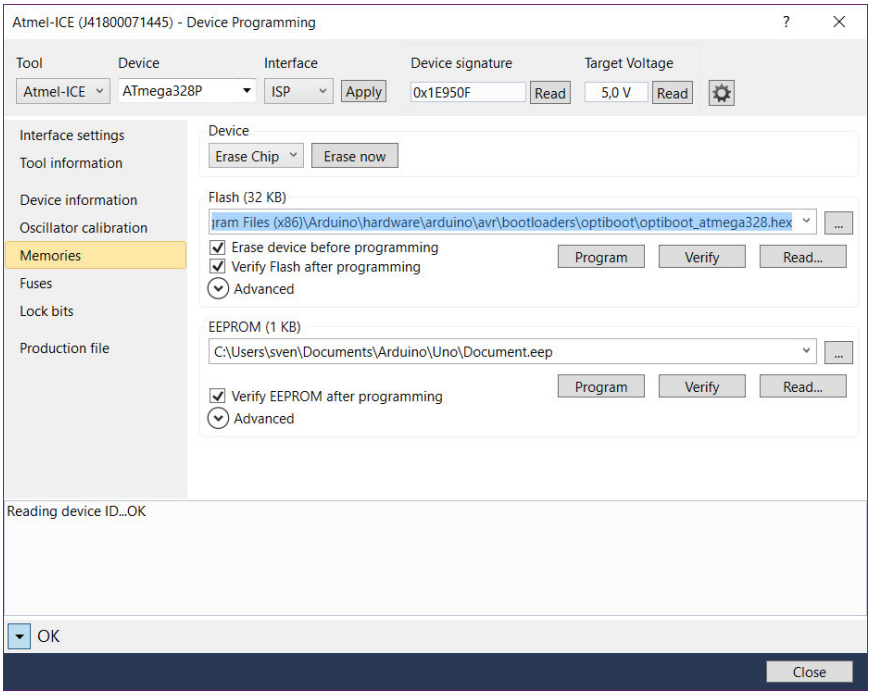


Figure 12: Programming the optiboot bootloader

It can be found here:

```
C:\Program Files (x86)\Arduino\hardware\arduino\avr\bootloaders\optiboot
```

The file name is:

```
optiboot_atmega328.hex
```

The hex-file can be loaded into the program buffer. Follow the steps like shown in Figure 1 and Figure 2, then select memories and for the Flash, select the file optiboot_atmega328.hex from the location described before.

The fuse settings are not contained in the *.hex file, they have to be programmed separately (see Figure 5).

Programming the bootloader with TL866II+

The bootloader that can be found in the Arduino software installation (see previous chapter) can also be programmed with the TL866II+ or TL866A. Please refer to Figure 6 to Figure 10. Remember, it is the file optiboot_atmega328.hex. The fuses are set exactly the same and need to be programmed.

Compiling and Uploading an Arduino sketch

The complete software for the Kernal Switch consists of two parts: the optiboot bootloader and the complied (and actually linked) Arduino sketch (c64kbksw.ino).

Once the bootloader is burnt, the sketch can be transferred via a serial cable as described in document number 128-6-04-00 (Wiring) and a required USB/Serial adaptor.

First the sketch has to be copied to the Arduino sketch folder (usually …\Documents\Arduino\c64kbksw). The sketch has to be opened (File → Open). After the Kernal switch is connected to the USB/serial converter (and this to the PC) via the serial cable and the power is on, the Board (in the Tools menu) has to be set to Arduino/Genuino Uno. Then the Port has to be selected. The USB/Serial adapter will set up as a COM-Port. If there are no other COM-Ports on the PC, it is the only one, that will be listed in the (Tools → Port) list. In case you are not sure, press (windows key X) select the Device Manager and look it up in the COM & LPT section (top of the list). It should be something like "USB Serial Port (COMxx)" (xx is the number, you have to remember). In case there is more than one: disconnect the adapter and watch which port disappears and then connect it again and watch what appears.

Once you have found out and set the correct COM Port, the Kernal Switch is connected and powered, you can hit the "right arrow" (= upload icon, 2nd from the left). The sketch will be compiled and the uploaded. Alternatively, select "Upload" from the "Sketch" menu.

If it does not upload, first check the +5V from the USB-Serial adaptor. It can be measured between the +5V and the GND pin of the ICSP connector J2 (see Figure 7). Then, check the cable and finally check the soldering on the PCB (use a lens or microscope!).

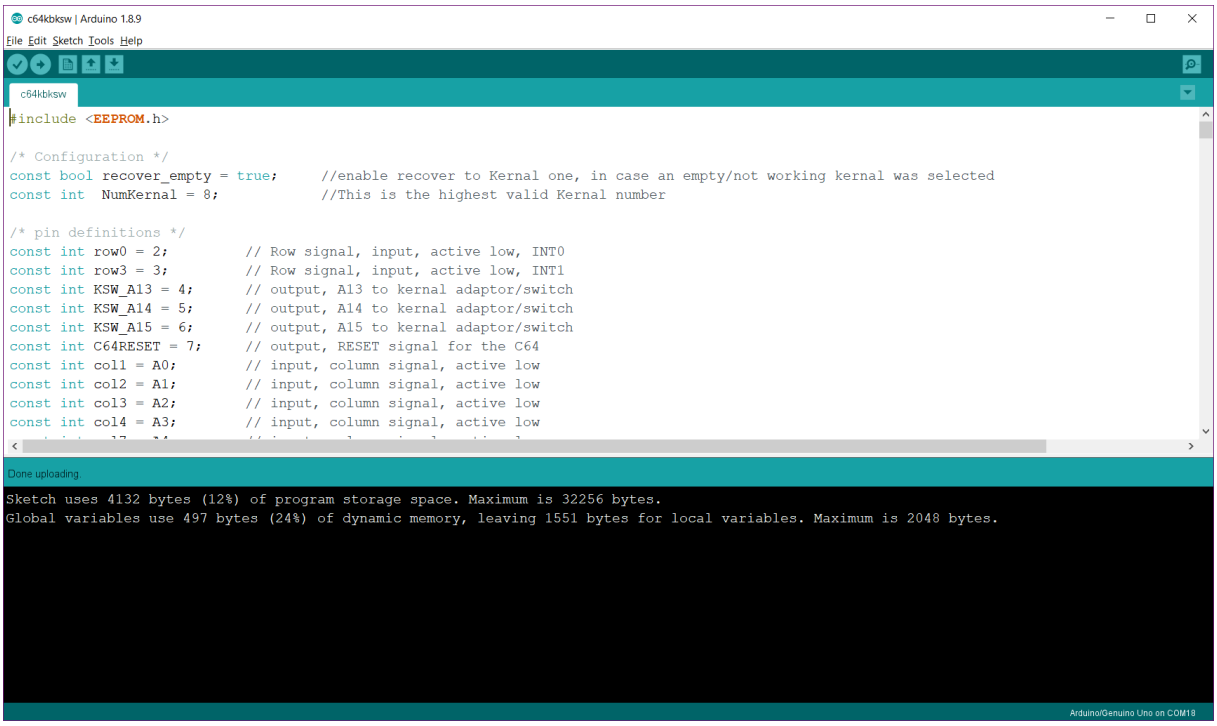


Figure 13: Compiling and uploading the sketch

C64 Keyboard Controlled Kernal Switch Rev. 0

Prototype Testing

Test Description

The test was executed with different models of the C64 mainboard.

- ASSY 250407 (Long Board)
- ASSY 250425 Rev. A (Long Board) in a C64C case
- ASSY 250469 Rev. 4 (Short board)

The Kernal Adapter (long board, short board) was selected to fit the C64 mainboard and the Kernal Switch was configured with the solder bridge CP1 accordingly.

All mainboards had a pin header (1 pin) installed to access their RESET-signal. The Kernal adapter and the Kernal switch were installed and wired.

The Kernal Adapter (Rev. 0) and the Kernal Switch (Rev. 0) was installed, the firm seat was checked and the cable were made and installed.

The test was carried out with seven different Kernals:

Number	Kernal
1	Original Commodore
2	JiffyDOS (6.01)
3	JaffyDOS (1.3)
4	EXOS v3
5	SpeedDOS
6	DolphinDOS 2.0
7	Turbo Tape v0.1
8	No Kernal (long board only)

The EPROM of the short board version contained the Commodore BASIC in the first 8k, the last 8k of the long board EPROM was left empty.

Mechanical Fit

Installation **ASSY 250469 Rev. 4**: The Kernal Adaptor is not colliding with any other components, some had to be bend in one direction to give some space to the PCB. The Kernal Switch was above U18, no collision detected.

RP4 had to be bent backward, slightly. All other components were far enough away. The board was seating well, the contact of J1 was sufficient. No contact between the solder side through hole pads and components of the C64 mainboard. It might be possible to get contact between those and the ground frame of ASSY250469, when the module is not seated well.

It is recommended to tape the solder side south of the keyboard connectors to prevent this.

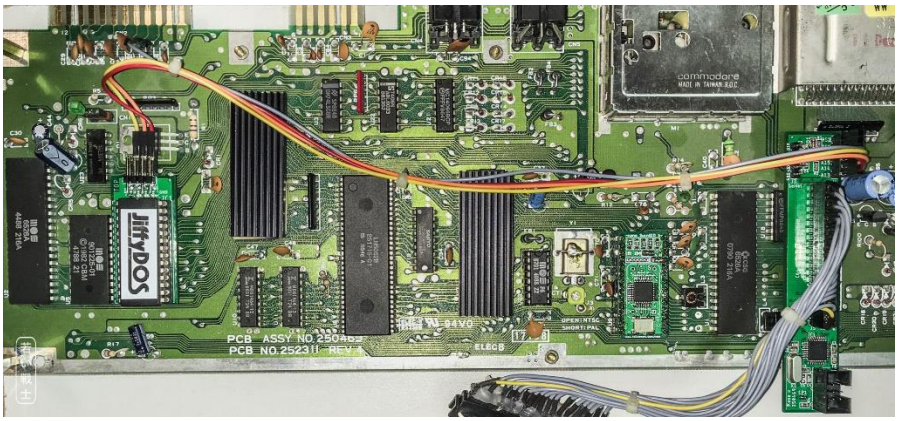


Figure 1: Installation ASSY250469

Installation **ASSY 250425 Rev. A in C64C case:**

The module fits on the board, it is seated properly, the contact of J1 is sufficient. The keyboard brackets do not collide with the PCB, the space is sufficient for the ICSP connector J2.

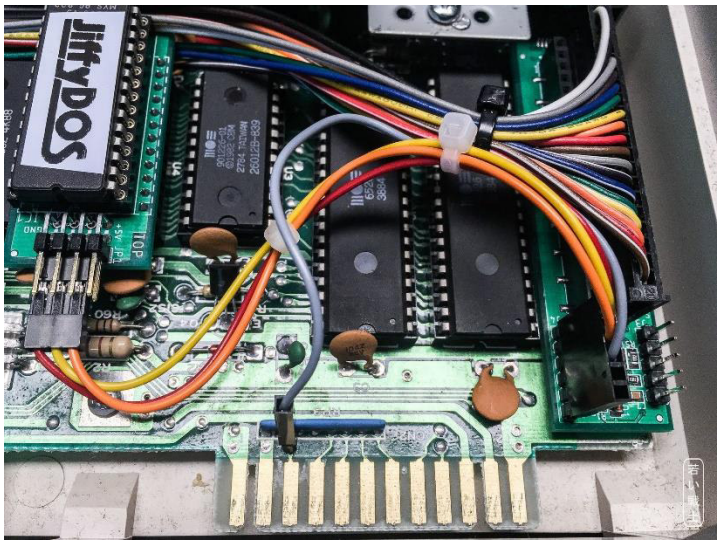


Figure 2: Installation ASSY250425

The protection diodes that are placed on top of other components on most ASSY250425 fit under the PCB. Since it is possible, that these diodes make contact with the through hole pads of the module, it is **required to tape the solder side of the board south of the keyboard connectors.**

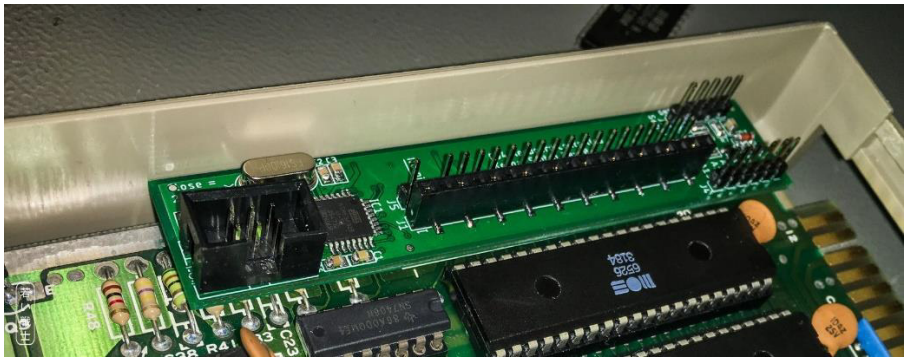


Figure 3: Installation ASSY250407 in bread bin case

Installation **ASSY 250407 Rev. B in bread bin case**:

The module fits on the board, it is seated properly, the contact of J1 is sufficient. The PCB does not collide with the components of the C64 south of the keyboard connector. It might be possible, that the pins of J2 scratch the resistors underneath it.

It is recommended to tape the solder side of the module south of the keyboard connector.

Test of functionality

Long Board version

The long board can switch between 8 Kernals. The EPROM was programmed with seven Kernals plus an empty 8th 8k EPROM slot.

Holding the RESTORE key

Holding the RESTORE key for several seconds generated a RESET of the C64. This was reported on the serial interface. This test was carried out >20 times.

Switching the Kernals

Pressing the number keys was detected properly and reported on the serial interface. Holding the RESTORE key and pressing a number key lead to changing the Kernal and resetting the C64. This worked like desired. The RESET pulse for the C64 was LOW for approximately 2 seconds.

All seven Kernals were tested several times each. No unwanted behavior was found.

Power Cycle

Switching Kernals and at least 20 power cycles per Kernal were performed. The previously selected Kernal was executed after the power cycle. The value is properly stored in the (non-volatile) EEPROM of the microcontroller. No unwanted behavior was found.

Switching to an empty Kernal

After selecting a valid Kernal, it was pressed RESTORE 8 to switch to the empty Kernal. The result was a crash of the C64. One character on the screen is cycled quickly, nothing else was visible. After a timeout of several seconds, the module reported “no keyboard activity” on the serial interface, switched to Kernal 1 and reset the system. The C64 restarted with Kernal 1 (the original Kernal). The desired recovery procedure worked properly. The test was carried out several times, starting from each of the valid Kernals.

Short Board version

The short board can switch between 7 Kernals. The EPROM was programmed with BASIC and seven Kernals.

Holding the RESTORE key

Holding the RESTORE key for several seconds generated a RESET of the C64. This was reported on the serial interface. This test was carried out >20 times.

Switching the Kernals

Pressing the number keys was detected properly and reported on the serial interface. Holding the RESTORE key and pressing a number key lead to changing the Kernal and resetting the C64. This worked like desired. The RESET pulse for the C64 was LOW for approximately 2 seconds.

All seven Kernals were tested several times each. No unwanted behavior was found.

Power Cycle

Switching Kernals and at least 20 power cycles per Kernal were performed. The previously selected Kernal was executed after the power cycle. The value is properly stored in the (non-volatile) EEPROM of the microcontroller. No unwanted behavior was found.

Test with Cartridges

The following cartridges were tested with the Kernal Switch:

- Final Cartridge 3+
- Power Cartridge
- Dela Dos
- Forth 64
- Diagnostic Rev. 586220
- 1541 Diagnostic/Test
- Ultimate II+
- Dead Test Rev. 781220

Except the Dead Test, all cartridges worked as desired, no unwanted behavior was found. Several power cycles were performed. The Diagnostic Rev. 586220 is configured as an EXROM cartridge, so at least initially, some keyboard scans are found.

The Dead Test cartridge does not perform keyboard scans. Thus, the Kernal Switch will reset the C64 after the time out of several seconds without keyboard scanning. This behavior was expected.

To provide non-interfered operation for this kind of cartridge, the module can be deactivated by pressing RESTORE 0 (zero). This was conducted: The Kernal was changed to Kernal 1. After switching off the C64, installing the Dead Test cartridge and powering up the computer again, the Dead Test was performed properly. The deactivation state was stored properly in the (non-volatile) EEPROM of the ATmega238P. Several tests cycles were performed. After unplugging the cartridge, the deactivation mode was switched off by selecting any of the Kernals. The state of activation was properly reported on serial interface. **The desired behavior was shown**.

Conclusion

The Keyboard Controlled Kernal Switch is fully functional.

Note: Not all mainboard and case type combinations could be tested. Also, the used parts may vary. An assessment of a proper installation and suitable connector seat of the keyboard connector J5 and the bottom entry connector J1 should be performed with every installation.

It is required to tape the solder side in the area south of the keyboard connectors to prevent short circuit or scratching the parts underneath the module.

C64 Keyboard Controlled Kernal Switch Rev. 0
Bill of Material Rev. 0.0

Pos.	Qty	Value	Footprint	Ref.-No.	Comment
1	1	128-2-01-00	2 Layer	PCB Rev. 0	2 layer, Cu 35µ, HASL, 101.2mm x 20.0mm, 1.6mm FR4
		copper structure on pcb		CP1	no part, open Cutpad, close for ASSY250469
	1	1x20	1X20	J5	pin header 1x20pin, 2.54mm pitch
	1	1x6	1X06	J4	pin header 1x6pin, 2.54mm pitch
	5	100n	0805	C1, C2, C3, C6, C7	SMD capacitor
	4	10k	0805	R1, R2, R4, R5	SMD resistor, 5% or better
	1	1M	0805	R3	SMD resistor, 5% or better
	2	1k	0805	R6, R7	SMD resistor, 5% or better
	2	22p	0805	C4, C5	SMD capacitor
	1	ATMEGA328P-AU	QFP80P900X900X120-32N	IC1	Atmel/Micro Chip, e.g. Farnell 2443176
	1	BC846B	SOT23	Q1	SMD transistor
	1	16 MHz/20pF quarz	HC49SLF	X1	e.g. Fox Electronics, FOXSLF/160-20, Farnell 2063950
	1	LL4148	SOD80C	D1	SMD diode
	1	M20-7862042	M20-7862042	J1	Harwin, e.g. Farnell 1256661
	1	WSL 6G	2X03WV	J2	box pin header, 2x3pin, 2.54mm pitch
	1	1x5	1X05	J3	pin header 1x5pin, 2.54mm pitch