

Creating edink from DINK32 Code Using the e500 ISS

*Authors: Amanuel Belay and Maurie Ommerman
Digital Systems Division
Freescale Semiconductor, Inc.
Austin, Texas*

This application note describes the process of creating a debugger (edink) from the DINK32 source code. It then explains how to run the edink executable on the e500 Instruction Set Simulator (ISS).

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1 Introduction

This document describes the method and coding for the e500 edink program running on the e500 ISS.

1.1 Terminology

The following terms are used in this document.

| | |
|--------------|--|
| Bash shell | Extension to the Bourne shell, which is popular on Linux systems and is sometimes called GNU Born Again Bourne Shell. This is the default shell for most Linux systems because Linux uses GNU tools exclusively. This is the best shell running the ISS. |
| Boot | Program that begins at hardware reset, which prepares the hardware for loading an operating system |
| Boot address | Address from which the board will attempt to boot after reset |
| BR | Base address register |
| Compiler | A software program that converts a high level source code into machine-specific binary |
| CPU | Central processor unit, that is the e500 processor |
| DDR | Dual data rate SDRAM |
| DINK32 | Small operating system debugger for the Sandpoint evaluation board |
| edink | Small operating system debugger for the e500 processors and the MARS platform |
| Host | A machine that can be used to build kernels. The host may or may not be the same architecture. For example, Freescale builds kernels on G4 machines, UNIX machines, and Intel machines. |
| ISS | A software model that simulates instruction processing capability of a processor |
| LAW | Local access window |
| MARS | Evaluation board platform for the MPC8540 and MPC8560 processors |
| OR | Option register |
| OS | Operating system |
| PCI | Peripheral component interface |
| RAM | Random access memory |
| Scrub memory | Setting memory with known values |
| SDRAM | Synchronous dynamic RAM |

2 What is edink?

edink is DINK ported for the e500 core based processors. DINK stands for Demonstrative Interactive Nano Kernel and is the program that boots and configures the Sandpoint evaluation system. Like DINK, edink boots the e500 core, enables caches, defines TLBs, and jumps to a prompt loop. Before a processor with an e500-based core was available in production quantities, edink was tested on a simulator. Currently, edink also runs on the Elysium board.

3 edink Startup

The e500 core boots from the address of 0xFFFF_FFFC. At boot time, one TLB entry is defined for an address space of 4K starting at 0xFFFF_F000. A branch instruction must be placed at address 0xFFFF_FFFC to branch to an address within the configured 4K space. From there more TLB entries can be defined.

When edink boots it jumps to 0xFFFF_F000. Then edink performs the following MPC8540 initialization in sequence:

1. Temporarily sets the interrupt vector offset registers (IVORs) and interrupt vector prefix register (IVPR) to 0xFFFF_F000 so that if exception occurs it goes to a TLB covered area.
2. Sets up the PID registers. Edink uses the PID register value of 0x0000_0000. The other two PID registers are programmed with the values of 0x0000_0001 and 0x0000_0002.
3. Sets up time base and decremter.
4. Invalidates the L1 and L2 TLB entries. Specifically, the IL1MMU, IL2MMU, L2TLB4K, and L2TLBCAM.
5. Sets up additional TLB entries. The TLB entry structures are discussed in [Section 4, “Memory Map,”](#) of this document.
6. Invalidates and turns on L1 cache. The simulator does not support the L2 and L3 cache. Consequently, edink does not attempt to enable the L2 and L3 caches.
7. Relocates the Configuration, Control, and Status Registers Base Address Register (CCSRBAR) to 0xFC00_0000.
8. Sets up Local Access Window (LAW) registers. For details see [Section 4, “Memory Map.”](#)
9. Initializes console I/O.
10. Configures local bus controller.
11. Configures DDR memory controller.
12. Configures PCI.
13. Scrubs memory and copies the exception table and the rest of edink (except the boot code, startup.S) to low memory (RAM) starting at address 0x0000_0000.
14. Sets up the IVORs and the IVPR to point to the exception table in SDRAM. The structure of the exception table is discussed in [Section 5.1, “Exception Handling.”](#)
15. Defines stack space. Stack space is described in [Section 5, “Stack Space for edink.”](#)
16. Sets up the MSR value to 0x0200_0000 and return from instructions (RFIs) to the main program. The bit set in the MSR value corresponds to SPE enablement.

4 Memory Map

Unlike processors that implement the classic PowerPC™ architecture, the e500 is based on the embedded PowerPC architecture (Book E). These processors use TLBs rather than BAT registers. For a detailed description of TLB entries and how to program them refer to the MPC8540 or MPC8560 processor's reference manual.

At reset, a 4K memory space is predefined starting at 0xFFFF_F000 with supervisor read, write, and execute permission. This memory area is caching inhibited. The startup code (in 'startup.S') sets up the processor, the TLBs (to enable more than 4K), the Local Access Windows (LAWs) to access internal peripherals, and the corresponding embedded device setup.

Note that the CCSRBAR is relocated from the default 0xFF70_0000 to 0xFC00_0000.

Once initialization is complete and the system has been setup, the memory map shown in [Table 4-1](#) is available.

Table 4-1. EDINK Memory Map

| Start Address | End Address | Size (MB) | TLB ¹ | LAW | BR/OR | Description |
|---------------|-------------|-----------|------------------|-----|-------|------------------|
| FF00_0000 | FFFF_FFFF | 16 | 0 | 0 | 0 | Flash array #1 |
| FE00_0000 | FEFF_FFFF | 16 | | | 1 | Flash array #2 |
| FD10_0000 | FDFF_FFFF | 15 | | | — | Unused |
| FD00_0000 | FD0F_FFFF | 1 | | | 2 | 8K NVRAM |
| FC10_0000 | FCFF_FFFF | 15 | | — | — | Unused |
| FC00_0000 | FC0F_FFFF | 1 | | — | — | CCSRBAR |
| F000_0000 | FBFF_FFFF | 192 | | — | — | Unused |
| E000_0000 | FFFF_FFFF | 256 | 3 | — | — | Unused; test |
| C000_0000 | DFFF_FFFF | — | — | — | — | Unused |
| A000_0000 | BFFF_FFFF | 512 | 6 & 7 | 3 | — | RapidIO I/O |
| 9000_0000 | 9FFF_FFFF | 256 | 5 | 2 | — | PCI IO space |
| 8000_0000 | 8FFF_FFFF | 256 | 4 | | — | PCI memory space |
| 2000_0000 | 7FFF_FFFF | — | — | — | — | Unused |
| 0000_0000 | 1FFF_FFFF | 512 | 1 & 2 | 1 | — | DDR SDRAM |

¹ Note that some address spaces require more than one TLB to be covered.

5 Stack Space for edink

Classic Dink R12.3 only had 0x0001_0000 = 65K decimal stack space, which was divided into four stack memory spaces, Dink CPU0 and 1 and User CPU0 and 1. This allowed only 4K for each stack.

Stack space for classic dink R13.0 has been increased to 0x0004_0000 and is still allocated to four stack areas. This allows 0x0001_0000 = 64K decimal for each stack space. This means that user code will start at 0x0010_0000. Edink uses the same larger stack space for one CPU.

The stack space is setup before edink jumps to main. R1 is used as the stack pointer. Stack space starts at the end of edink RAM location (0x000C_0000) and extends to the beginning of user space (0x0010_0000). The stack space map is shown in [Table 5-1](#).

Table 5-1. Stack Space

| Address | ROM | |
|-------------|-----|----------------------|
| 0x000F_FFE0 | | Start of edink stack |
| 0x000E_0000 | | End of edink stack |
| 0x000D_FFE0 | | Start of user stack |
| 0x000C_0000 | | End of user stack |

5.1 Exception Handling

Unlike classic PowerPC based processors, e500 core has programmable exception vector locations. The registers designate the interrupt vector offset while the IVPR register designates the start address of the interrupt vector table. For edink, the interrupt vector addresses remain as compatible as possible with PowerPC classic. The e500 interrupt vectors not previously defined by the classic processors occupy an address that was not used by classic DINK. [Table 2](#) shows the IVOR register, address offset and interrupt name for each interrupt vector that is implemented in edink.

Table 2. Exception Table Addresses

| VOR Number | Address | Interrupt Type |
|------------|---------|---|
| IVOR0 | 0x0100 | Critical input |
| IVOR1 | 0x0200 | Machine check |
| IVOR2 | 0x0300 | Data storage |
| IVOR3 | 0x0400 | Instruction storage |
| IVOR4 | 0x0500 | External input |
| IVOR5 | 0x0600 | Alignment |
| IVOR6 | 0x0700 | Program |
| IVOR7 | 0x0800 | Floating-point unavailable (not supported on the e500) |
| IVOR10 | 0x0900 | Decrementer |

Table 2. Exception Table Addresses (continued)

| VOR Number | Address | Interrupt Type |
|------------|---------|---|
| IVOR9 | 0x0A00 | Auxiliary processor unavailable (not supported on the e500) |
| IVOR11 | 0x0B00 | Fixed-interval timer interrupt |
| IVOR8 | 0x0C00 | System call |
| IVOR12 | 0x0D00 | Watchdog timer interrupt |
| — | 0x0E00 | Not Used |
| IVOR35 | 0x0F00 | Performance Monitor |
| IVOR14 | 0x1000 | Instruction TLB error |
| IVOR13 | 0x1100 | Data TLB error |
| IVOR33 | 0x1200 | SPE floating-point data |
| IVOR34 | 0x1300 | SPE floating-point round |
| — | 0x1400 | Not Used |
| IVOR15 | 0x1500 | Debug |
| IVOR32 | 0x1600 | SPE APU unavailable |

There are three types of exceptions in the e500 core. These are:

- Normal exceptions which are identical to the classic exceptions
- Critical exceptions which include the critical class exceptions
- Machine check exception.

Consequently, there are three handlers for the three types of exceptions: `normal_handle_ex` handles the normal exceptions, `critical_handle_ex` handles the critical exceptions, and `machine_handle_ex` handles the machine check exception. All the exception handlers restore the registers, print out exception names, and causal addresses and return one of two locations depending on the following cases:

- If the exception has occurred while edink is running the return address is where edink was last executing before the exception
- If the exception has occurred while edink is running user code the return address is dink loop

Normal exceptions return using the **rfi** instruction, while critical and machine check exceptions use **rftci** and **rftmci** instructions, respectively. At the time of this writing normal exceptions are fully implemented, however, critical and machine check exceptions are not fully implemented.

Critical and machine check exceptions will loop on a branch to self instruction forever, and the following registers are set up:

- r10 = type of exception (that is, the address of the exception table for this exception)
- r11 = address that caused the exception.
- r12 = the user msr at the time of the exception.

6 e500 Instruction Set Simulator

The e500 instruction set simulator (ISS) is a non-cycle accurate software model of the e500. The model features the following:

1. MMU: virtual memory translation and permissions using TLB entries
2. Instruction and Data L1 cache: and all the L1 cache support instructions
3. Memory: simulated memory includes address range of 0x0000_0000 – 0xFFFF_FFFF accessible through load and store instructions.
4. Interrupts: simulates exception handling
5. Boot from 0xFFFF_FFFC

The model does not support the following:

1. Cycle accuracy: the model does not have a sense of clock cycles. It crunches instructions in order with no cycle latencies.
2. Out of order instruction execution.
3. Microarchitectural pipeline is not modeled.

Furthermore, a simulator portal (sportal) is attached to the ISS that enables Input/Output for the simulator. The sportal facility is discussed in [Section 6.1, “Sportal Facility”](#).

6.1 Sportal Facility

The simulator portal (sportal) facility simulates input/output for the ISS. The sportal provides an application programming interface (API) that is called when sc (system call) instructions are encountered. To use the API one has to include a header file and a library (appPortal.[ho]) provided with the ISS and call the desired routines. The functions used by edink in the API are:

1. `sim_fprintf`: used for debugging
2. `sim_putc`: used to put a character to the sportal terminal
3. `sim_getc`: used to get a character from the sportal terminal
4. `sim_exit`: used to exit (quit) the simulator

Edink when compiled for the simulator redirects all `putc` and `getc` functions to `sim_putc` and `sim_getc` respectively.

Unrecognized system calls are trapped as regular system calls and the software that is running on the ISS is expected to handle them.

The APIs can also be directed to a file instead of a terminal. The command lines to enable the sportal are shown below.

- `sportal_open`: this command enables the sportal facility.
- `sportal <stream_type> <stream>`: this command specifies which stream to direct to what device (or file). `<stream_type>` is one of the following:
 - `sim_stdin`: for standard in
 - `sim_stdout`: for standard out

- `sim_stderr`: for standard error
- `sim_stdall`: for all the above streams

The `<stream>` parameter can be the word ‘term’ for a terminal or a file name. For example, to open an sportal with the input directed from a file “my_stdin.txt” and the output directed to the terminal, the following commands are used from the ISS command prompt:

```
>> sportal open
>> sportal sim_stdin my_stdin.txt
>> sportal sim_stdout term
```

For further usage of the sportal facility refer to the sportal user’s manual provided with the ISS in the `simPortal/doc` directory.

Two example sportal files are supplied with edink, one for file input/output (I/O) and one for emulated terminal I/O.

6.2 Invoking the ISS with the Sportal

cd to appropriate directory

```
iss
source src/sportal_file or source src/sportal_term
go
```

6.3 sportal_file

```
sportal open
sportal sim_stdin src/my_stdin
sportal sim_stdout my_stdout
sportal sim_stderr my_stderr
ld obj/edink
```

6.4 sportal_term

```
sportal open
sportal sim_stdall term
ld obj/edink
```


7 Compiler

An e500 core aware compiler/assembler tool chain should be used to build the code.

E500 compilers do not generate floating point instructions. If your compiler does not understand these instructions then try the following:

- Signal Processing Engine (SPE) instruction
 - can be coded with `.long` using the hex equivalent of the instruction
- the **msync** instruction
 - is generated by the **sync** instruction

The following instruction, while supported, has a different form than shown in *EREF: A Reference for Freescale Book E and the e500 Core* (EREF/D).

- **tlbwe** instruction

The compiler requires three parameter registers (tlbwe **rA**, **rB**, **rC**) to the instruction. These registers are un-altered by the architecture (machine).

8 e500 Core Registers versus Classic PPC Registers

For descriptions of these registers refer to the *EREF: A Reference for Freescale Book E and the e500 Core* (EREF/D), *PowerPC e500 Core Complex Reference Manual* (e500CORERM/D), and *PowerPC e500 Applications Binary Interface User's Guide* (e500ABIUG/D).

Some of the classic PowerPC registers are supported on the e500 core. However, some of the classic registers do not exist on the e500 core including the following:

- `dsisr`, `dar`, `sdr1`, `ear`, all bat registers, `ummc2`, `upmc(n)`, and `usia`

Furthermore, e500 adds many new registers that didn't exist in classic PowerPC. These registers are listed below:

- `decar`, `csrr0`, `csrr1`, `dear`, `esr`, `ivpr`, `usprg(n)`, `pir`, `dbsr`, `dbcr(n)`, `iac(n)`, `dac(n)`, `tsr`, `tcr`, `ivor(n)`, `spefscr`, `bbear`, `bbtar`, `l1cfg(n)`, `npdir`, `iarr`, `mcsrr(n)`, `mcsr`, `mcar`, `mas(n)`, `pid(n)`, `tlbcrf(n)`, `hdbcr(n)`

Some of the e500 register SPR numbers are the same as classic registers but have different uses. The following e500 registers have SPR numbers that are used for other registers in classic PowerPC:

- `usprg0`, `ivor32`, `ivor33`, `ivor34`, `ivor35`, `mcsrr1`, `mcsr`, `mcar`, `hdbcr4`, `hdbcr5`, `l2csr0`, `l1csr1`, `mmucsr0`, `bucsr0`, `mmucfg`, `svr`.

9 Code Changes

Several new files are written for edink. Some of these are e500.h, vector.S, startup.S and except2e.S. edink boots up from vector.S. There are two reasons why the boot file is written on a separate assembly file.

1. Having a boot code that is separate from the exception table is a cleaner approach.
2. e500 core boots at an address of 0xFFFF_FFFC. Having a single file with the exception table (which is located starting at 0x0100) and the high address of 0xFFFF_FFFC is not convenient for linking.

except2e.S contains the exception table. The exception table is similar to the classic dink exception table and may eventually be integrated with the classic dink.

Several classic dink files are modified for edink. The following are the major changes:

- main.c
 - new entry in mach_info for MARS
 - call initialize functions only for e500
- reg_swap.S, spr_loc.h, dink_asm.h, reg_fields.h
 - all the new and changed SPRs are handled here for dink initialize, save and restore.
- config.h
 - define MARS and PPC. The PPC is defined for future MPC8540 and MPC8560 specific code changes.
- shell.c
 - define new command, sq - simulator quit.
 - suppress terminal echo for standard I/O files
- par_tb.c, pmc.c
 - splash screen changes
- print.c
 - suppress ^M printing on sportal file I/O
- go_tr1.c, except1.c
 - don't execute cache flush for L2 or L3. e500 simulator doesn't support them
- reg_spr.c
 - srr1 user msr changed to 0x0200_0000.
 - define e500 SPR fields for the "sx" command
- uart.c, rtc.c, iolib.c
 - minor changes

All other files are being used without changes.

10 edink Availability

Edink limited source will be available on the Freescale web site with the rest of the classic DINK R13.1. Full source can be obtained with a license agreement.

10.1 Source Files

As released on the web, the full and limited source only differ in the number of source files that are available. The limited release typically includes only the source necessary to bring up the board.

- vector.S, startup.S, except2e.S, main.c, reg_swap.S, spr_loc.h, dink_asm.h, reg_fields.h, config.h, except1.c, all the readme files, and the sportal files.

The full release contains all the source code necessary to build and run edink R13.0, including the makefiles.

10.2 Executable Files

The limited release includes the srecords, edink_mars_e500gcc.src, edink_marssim_e500gcc.src and edink_iss_e500gcc.src.

The full source does not include any executables. All the listed files above can be created and also a disassembly of the edink can be created.

10.3 Directory Structure

The source is released as a zip file. Once unzipped the structure will look like this.

- toplevel
 - makefile: This is the location for invoking the ISS, see [Section 12, “Example Run.”](#)
- toplevel/obj
 - all object files, executables, and cross reference files
- toplevel/src
 - either full source files or limited source files
 - sportal files and readmes

11 edink Splash Screen

```
I/O system initialized...
Environment is not valid...
Skipping system setup...
Memory Enabled: [ 64MB at CL=3 ]
Caches Enabled: [ none ]
Register Inits: [ 32 GPRs, 155 SPRs ]
Assembler Init: [ 895 opcodes ]
```

Example Run

```

                ##  ##                ##
                ##  ##                ##
                ##                ##
#####          ##### ## ##### ##
##  ##  ##  ##  ##  ##  ##  ##  ##
#####  ##  ##  ##  ##  ##  #####
##      ##  ##  ##  ##  ##  ##  ##
#####  #####  ##  ##  ##  ##  ##

```

Version : 13.1, GCC Build

Released : Built on Apr 30, 2003 11:28:00

Written by : Freescale's RISC Applications Group, Austin, TX

System : Instruction Set Simulator

Processor : MPC8540 V1.0 @ (simulated) MHz, Memory @ simulated MHz

Memory : 4GigBytes simulated memory

12 Example Run

This example uses the `sportal_file` as explained in [Section 6.3, “sportal_file.”](#) Once this file is sourced then the ISS will use the `src/my_stdin` file as input to `edink` and generate the file `my_stdout`. The ISS will read the `src/my_stdin` file handing each character to `edink` who will then generate the `my_stdout` file. `src/my_stdin` file has the `sq`, simulator quit, command as the last line, which will invoke the ISS exit code.

12.1 invocation

```

iss
e500( idle )>source src/sportal_file
File indicated entry point of: 0xFFFFFFFFC
Setting entry point
4160749439 bytes are available for your program's heap and stack.
e500( idle )>go
e500(running)>
Program exited with exit code 0
e500( idle )>exit

```

12.2 my_stdin File

```

on
rd r
rm r3
3
rm r8

```

```

8080
rd r
as 100000+
here:
lis r20,20
ori r20,r20,20
b here
x
ds 100000-100020
bp 100008
bp
sq

```

12.3 Generated my_stdout File

Hello sportal from sim_stdout

Do you desire echo on or off? Typically off for sim terminal, on for sim file io

Please type in "on" or "off" >>

You have chosen "on"

edink[MPC8540] {1} >>rd r

| | | | |
|---------------|--------------|--------------|--------------|
| R0 =00000000 | R8 =00000000 | R16=00000000 | R24=00000000 |
| R1 =0008FFFE0 | R9 =00000000 | R17=00000000 | R25=00000000 |
| R2 =00000000 | R10=00000000 | R18=00000000 | R26=00000000 |
| R3 =00000000 | R11=00000000 | R19=00000000 | R27=00000000 |
| R4 =00000000 | R12=00000000 | R20=00000000 | R28=00000000 |
| R5 =00000000 | R13=00000000 | R21=FF0456D8 | R29=00000000 |
| R6 =00000000 | R14=00000000 | R22=00000000 | R30=00000000 |
| R7 =00000000 | R15=00000000 | R23=00000000 | R31=00000000 |

edink[MPC8540] {2} >> rm r3

R03 = 00000000 ? 3

edink[MPC8540] {3} >> rm r8

R08 = 00000000 ? 8080

edink[MPC8540] {4} >> rd r

| | | | |
|---------------|--------------|--------------|--------------|
| R0 =00000000 | R8 =00008080 | R16=00000000 | R24=00000000 |
| R1 =0008FFFE0 | R9 =00000000 | R17=00000000 | R25=00000000 |
| R2 =00000000 | R10=00000000 | R18=00000000 | R26=00000000 |

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```

R3 =00000003      R11=00000000      R19=00000000      R27=00000000
R4 =00000000      R12=00000000      R20=00000000      R28=00000000
R5 =00000000      R13=00000000      R21=FF0456D8      R29=00000000
R6 =00000000      R14=00000000      R22=00000000      R30=00000000
R7 =00000000      R15=00000000      R23=00000000      R31=00000000

edink[MPC8540] {5} >> as 100000+
00100000 00000000      .WORD      0x00000000      here:
00100000 00000000      here:      .WORD      0x00000000      lis r20,20
00100004 00000000      .WORD      0x00000000      ori r20,r20,20
00100008 00000000      .WORD      0x00000000      b here
0010000C 00000000      .WORD      0x00000000      x

edink[MPC8540] {6} >> ds 100000-10000C
00100000 3E800020      here:      lis      R20,0x20
00100004 62940020      ori      R20,R20,0x20
00100008 48000000      b      0x100008
0010000C 00000000      .WORD      0x00000000

edink[MPC8540] {7} >> bp 100008
Breakpoint at 00100008

edink[MPC8540] {8} >> bp
Breakpoints:
1. 0x00100008

edink[MPC8540] {9} >> sq

```

13 Documentation Revision History

Table 13-1 provides a revision history for this application note.

Table 13-1. Document Revision History

| Rev. No | Substantive Change(s) |
|---------|---|
| 0 | Initial release. |
| 1 | Changes to comply with edink for the Elysium hardware. Removed section “problems encountered with simulator”. Added document revision history |
| 2 | Updated document to new Freescale template. |

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How to Reach Us:

Home Page:

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USA/Europe or Locations Not Listed:

Freescale Semiconductor
 Technical Information Center, CH370
 1300 N. Alma School Road
 Chandler, Arizona 85224
 1-800-521-6274
 480-768-2130
 support@freescale.com

Europe, Middle East, and Africa:

Freescale Halbleiter Deutschland GmbH
 Technical Information Center
 Schatzbogen 7
 81829 Muenchen, Germany
 +44 1296 380 456 (English)
 +46 8 52200080 (English)
 +49 89 92103 559 (German)
 +33 1 69 35 48 48 (French)
 support@freescale.com

Japan:

Freescale Semiconductor Japan Ltd.
 Headquarters
 ARCO Tower 15F
 1-8-1, Shimo-Meguro, Meguro-ku
 Tokyo 153-0064, Japan
 0120 191014
 +81 3 5437 9125
 support.japan@freescale.com

Asia/Pacific:

Freescale Semiconductor Hong Kong Ltd.
 Technical Information Center
 2 Dai King Street
 Tai Po Industrial Estate,
 Tai Po, N.T., Hong Kong
 +800 2666 8080
 support.asia@freescale.com

For Literature Requests Only:

Freescale Semiconductor
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