Transitioning from uclIBC to musl for embedded development

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What is musl?

**musl** is a libc, an implementation of the user-space side of the standard C/POSIX functions that are the foundation of most systems.

**musl** is a *general-purpose* libc. Unlike uClibc, it's not specific to the embedded domain.
History and Motivations

- Based on work that begin in 2005, seeking an alternative to glibc bloat with strong UTF-8 support.
- uClibc was an emerging option, but lack of stable ABI made it unattractive.
- Project really launched 2010-2011.
- Milestone 1.0 release in 2014.
Core Principles

Not all chosen from the outset, but evolved:

- Simplicity as the core approach to size, performance, security, and maintainability
- Factoring for minimal code duplication
- Ease of navigating and understanding code
- Robustness/fail-safety
- Not depending on fancy compiler/toolchain features
- First-class status for UTF-8, non-ASCII characters
Motivations for switching from uClibc to musl

Three major areas:

- Technical advantages
- Project health & development process
- License
License

uClibc is LGPL. musl is under a permissive (MIT) license:


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Permissive license means you can make static-linked binaries without license-conformance concerns.
Project Health

- Time-based releases every 1-2 months
- Tracking current standards
- Rapid turnaround for bug fixes
- Responsive mailing list and IRC channel
- Stable ABI
uClibc's declining health

- Almost 3 years with no official releases
- 3 options for threads, all outdated & buggy
- Numerous broken configurations
- Major C99 and POSIX 2008 features missing
- Buildroot considering switching away
Technical benefits of musl
Quantitatively

<table>
<thead>
<tr>
<th></th>
<th>musl</th>
<th>uClibc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source code size</td>
<td>~48kloc</td>
<td>~230kloc</td>
</tr>
<tr>
<td>Library binaries</td>
<td>~500k</td>
<td>~500k</td>
</tr>
<tr>
<td>Minimal static binary</td>
<td>1.8k</td>
<td>7k</td>
</tr>
<tr>
<td>Minimal printf static binary</td>
<td>13k</td>
<td>70k</td>
</tr>
<tr>
<td>Minimal threaded static binary</td>
<td>6k</td>
<td>114k</td>
</tr>
<tr>
<td>Dynamic linking overhead</td>
<td>20k</td>
<td>40k</td>
</tr>
<tr>
<td>UTF-8 performance</td>
<td>4x glibc</td>
<td>2x glibc</td>
</tr>
</tbody>
</table>

(Sizes vary by arch; measured on x86.)
Fail-safety

musl does not introduce unnecessary failure cases.

Operations that can be performed in-place or in small bounded space without resource allocation never fail.

After `main()` is entered, all failures are reportable. musl will never `abort()` behind the program's back.

No lazy binding or lazy TLS allocation.
Advanced posix_spawn()

The posix_spawn function is like fork+execve in one.

Avoids all the dangers of vfork (ewontfix.com/7/).

musl's posix_spawn implementation uses CLONE_VM and close-on-exec to synchronize with child's execve.

Compatible with NOMMU and optimal for low-memory environments.
Advanced threads implementation

- Lightweight - around 10-15k total.
- Supports C11 and POSIX threads APIs.
- Safe-to-use thread cancellation ([ewontfix.com/2](ewontfix.com/2)).
- Strong adherence to POSIX and C11 semantics.
- Available on all supported archs.
iconv charset conversions

musl's iconv() supports most major legacy character encodings, including legacy CJK & GB18030.

All in 128k of code & tables.
Important Differences
musl is *not* configurable

And that's a good thing.

For static linking, efficient factorization of object files gives most of the same benefits as configurable features would, but without the configuration burden on the user (you).

As a result, testing is practical and we don't have continually breaking feature combinations.
musl supports fewer archs

But it's easy to port.
Supported by both uClibc and musl

i386, x86_64, ARM, PowerPC, MIPS, Microblaze, SuperH
Supported only by uClibc

Alpha, AVR32, Blackfin, c6x, Cris, HPPA, Itanium, m68k, Nios, Sparc, Vax, Xtensa
Supported only by musl

AArch64, OpenRISC 1000
And hopefully (GSoC) RISC-V!
What's involved in a port?

- 12 mandatory asm files (~200 lines)
- 5 mandatory arch-def headers (~150 lines)
- 27 bits/ headers defining types/kernel interfaces
- Small build-system glue
- Optional optimized versions of bottleneck functions
musl doesn't use glibc headers

uClibc uses (outdated, modified) copies of the glibc headers and defines `__GLIBC__` to “trick” applications.

musl has its own clean-room headers.

musl's headers do not depend on any kernel headers, but may conflict with some uses of kernel headers.
musl is only one lib file

Threads, math, clock_gettime(), etc. are always available without needing -lm, -lpthread, etc.

Even the dynamic linker is integrated.

Empty libm.a, libpthread.a, etc. are provided for build-time compatibility (and conformance).

There is no libm.so, libpthread.so, etc.
musl behaves differently

In some ways.

But usually they're good, once you understand them.
Dynamic linking

- Always RTLD_NOW behavior (no lazy binding).
- Dynamic TLS is reserved at dlopen (no lazy allocation).
- Loaded libraries are never unloaded (by dlcclose).

As a result, most archs have zero lines of arch-specific dynamic-linker code.
Threads

- Default thread stack size is small (80k vs 2-8 MB).
- Thread cancellation doesn't interact with exceptions.
- Dynamic TLS is reserved at thread creation.
Locale and charset

- Character encoding is always UTF-8 (even C locale).
- Character properties are hard-coded to Unicode, not locale-specific and not generated from glibc locales.
- `iconv` supports different (mostly, more) charsets and may behave differently.
Further misc. differences

- Math functions don't set errno, only fenv flags.
- DNS lookups are done in parallel.
- Regex implementation has different/fewer extensions.
Toolchains & Distributions
Canonical toolchain is musl-cross

https://bitbucket.org/GregorR/musl-cross

These are the patches intended for gcc upstream and will eventually make it there.

Simple musl-targeted cross compiler build scripts are included. Precompiled x86 binaries available.
Buildroot supports musl

- Well-known to uClibc users.
- musl is an option on the toolchain menu.
- Still labelled “experimental”.
musl-based distributions

- Sabotage Linux - the original musl-based dist and patch-source for packages that don't build against musl out-of-the-box.
- OpenWRT - supports musl-based builds; plans to switch default to musl.
- Alpine Linux - server- and security-oriented distribution with binary packages for x86[_64] and ARM.
- Many more - see the musl community wiki.
Thank you

http://www.musl-libc.org

@musllibc, @RichFelker

https://www.patreon.com/musl