FreeBSD and NetBSD on Small x86 Based Systems

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Asia BSD Conference in Tokyo, Japan

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Introduction

Who am I?

- Ph.D. in Mathematical Physics (long time ago)
- Webgroup Consulting AG (now)
- IT Consulting Open Source, Security, Perl
- FreeBSD since version 1.0 (1993)
- NetBSD since version 3.0 (2005)
- Traveling, Sculpting, Go

Focus on Installing and Running FreeBSD and NetBSD on Compact Flash Systems

(1) Overview of suitable SW for small x86 based systems with compact flash (CF)

(2) Live CD / USB dists to try out and bootstrap onto a CF

(3) Overview of HW for small x86 systems

(4) Installation strategies: what needs special attention when doing installations to CF

(5) Building your own custom Install/Maintenance RAMdisk

FreeBSD for Small HW

Many choices! – Too many?

- PicoBSD / TinyBSD
- miniBSD & m0n0wall
- pfSense
- FreeBSD livefs, memstick
- NanoBSD
- STYX.

Others: druidbsd, Beastiebox, Cauldron Project, ...

PicoBSD & miniBSD

- PicoBSD (1998): Initial import into src/release/picobsd/ by Andrzej Bialecki <abial@freebsd.org

  Geared towards floppy-based systems: "Building picobsd is still a black art. The biggest problem is determining what will fit on the floppies, and the only practical method is trial and error"

- TinyBSD in src/tools/tools/tinybsd (since 2006)

  http://martenvijn.nl/trac/wiki/TinyBSD

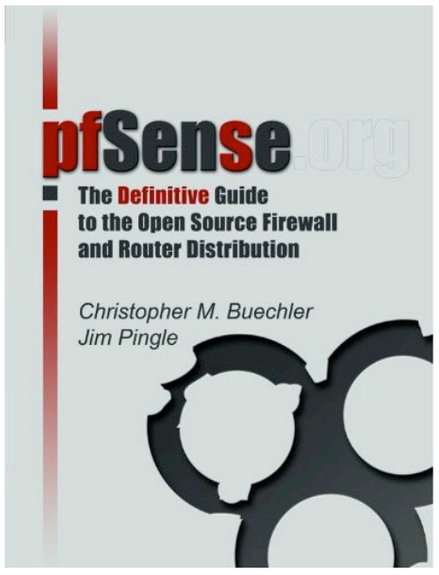
- miniBSD (2002): by Manual Kaspar as a precursor to m0n0wall (**https://neon1.net/misc/minibsd.html**) FreeBSD 4.x

- Other people made modifications to miniBSD to make it work for FreeBSD 5.x and 6.x

m0n0wall

- Full-fledged firewall with VPN, traffic shaping, VLAN, captive portal capabilities all in less than 12MB
- Boots into steady state in less than 25 seconds on PCEngines
- Configuration via a PHP web GUI and stored in XML
- No access to a shell nor file system, system is run from RAM
- Very much "end-user" oriented (i.e., burn & install CF, configure IP on console and rest in GUI, forget)
- CF images for PC Engines and Soekris, early versions ran on 4.x and now currently runs on 6.x (2-3 versions /year since 2005) see **m0n0.ch/wall/oldversions.php**
- Website **m0n0.ch/wall/** 2003-2010 Manuel Kasper

pfSense



- Started in 2004 as a fork of m0n0wall; As the name suggests, pfsense uses pf as default firewall filter (m0n0wall uses ipfw and more recently ipfilter)
- Contrary to m0n0wall, you can easily get shell access and modify the file system yourself; it also has packaging system to add additional features
- Very active development (1.x runs on 7.x) the forthcoming pfSense 2.0 will run on 8.x

- Website: **`www.pfsense.org/index.php`**
  2004-2011 Chris Buechler & Scott Ullrich, now BSD Perimeter LLC **`www.bsdperimeter.com`**

NanoBSD

- Part of FreeBSD source tree since 2004 in **`src/tools/tools/nanobsd/`** by Poul-Henning Kamp <phk@freebsd.org>

"Nanobsd should make it very simple for people to create (CF-)disk images for embedded use of FreeBSD"

- Rewrite from Makefile to Shell Script in 2005
- Geared to 256MB - 4GB CF, with up to three partitions "live", "fallback", and "config"
- CF geometry needs to be specified case-by-case because fdisk is done on vnode device

- A remote managed firewall *service* since 1998 by Adrian Steinmann <ast@styx.ch>
- Customers have a "read-only" web GUI for status of their "firewall appliance"
- Remote administration via SSH cmd-line Revision control: **www.webgroup.ch/pi**
- Remote OS upgrades via Secure Shell maintenance RAMdisk
- Tracks FreeBSD since 3.x, runs on 8.x

NetBSD on a Stick

"Of course it runs NetBSD"

Cookbook to install NetBSD onto a USB stick (2008):

www.bsdnexus.com/NetBSD_onastick/install_guide.php

As usual, NetBSD is simple and straight-forward – the recipe boils down to these command-line steps:

fdisk, disklabel, newfs, installboot, untar base.tgz and etc.tgz sets, make devices, fixup /etc/fstab – DONE!

NetBSD Live Key

imil.net/nlk

The NetBSD LiveKey project (2006) is a non-destructive NetBSD/i386 on a USB stick. It is composed of a tarball or zipfile to be uncompressed on a USB key without changing the original Filesystem (usually VFAT).

Uses grub to make USB stick bootable

Runs X11 with ion3, customizable

Developement has apparently ceased

... you will probably need about 256MB RAM to run the USB key smoothly ...

Live NetBSD CD

www.jibbed.org

Jibbed is a NetBSD-based Live CD, and the version number tracks NetBSDs and is on NetBSD 5.1.

"... features select packages from pkgsrc, as well as auto-configuration for networking and graphics cards. This version contains the xfce4 window manager and uses Xorg (base). It features vnd compression and is only 400 MB in size. The minimum requirement is now an i686 or compatible CPU and 128 MB RAM ..."

Creating NetBSD USB **installation** media

pbraun.nethence.com/doc/sysutils_bsd/netbsd_usb.html

based on

ftp.netbsd.org/pub/NetBSD/misc/jmcneill/mkmemstick.sh

basic idea is to take CD image or binary sets from release and create a bootable image file which can be copied raw to a USB stick with dd.

```
makefs netbsd.img path_to_root

installboot netbsd.img /usr/mdec/bootxx_ffsv1

disklabel -R -F netbsd.img disklabel.conf

dd if=netbsd.img of=/dev/rsd1d bs=1024k
```

Summary on SW

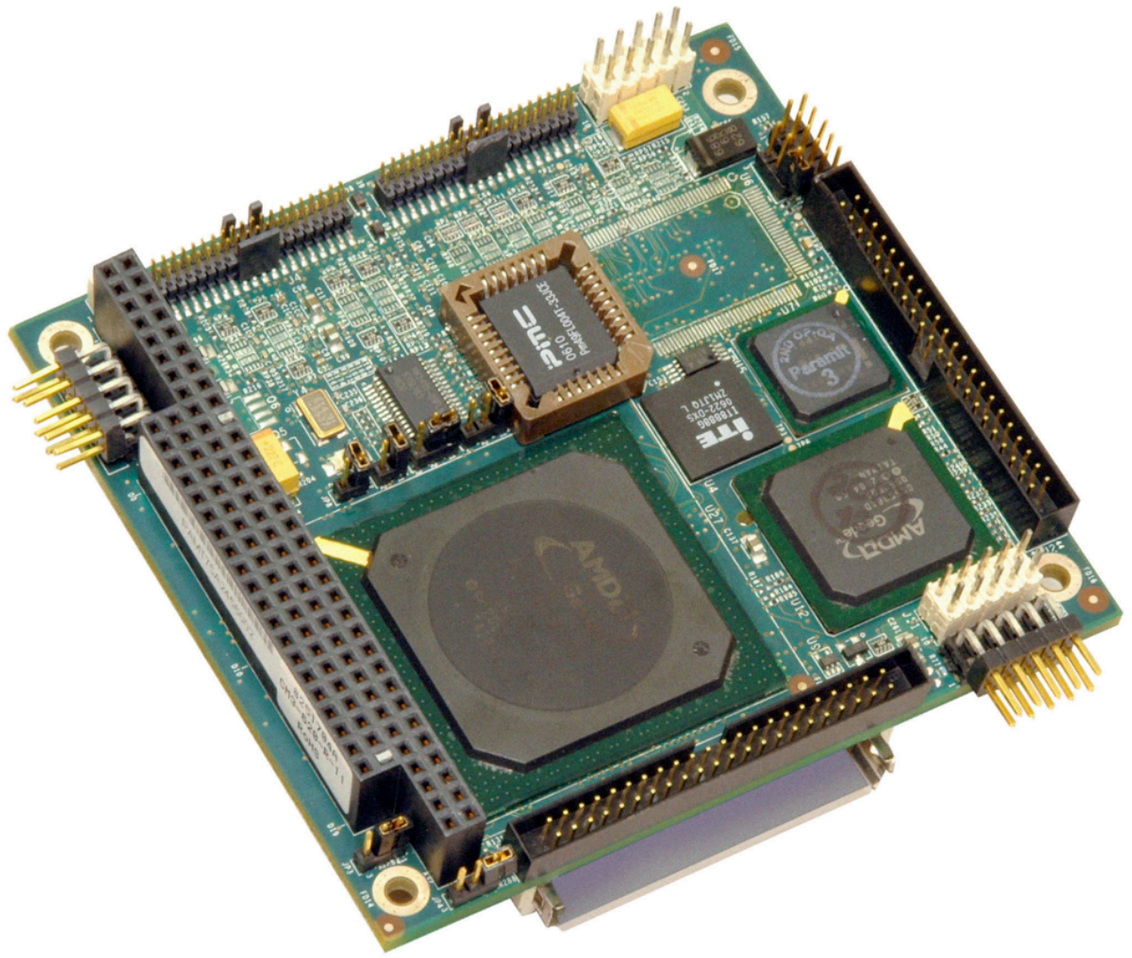
- Lots of images for FreeBSD available, some of them a bit dated – the earliest ones tried to fit on 1.4MB floppies, with today's kernel sizes that is impossible
- Less images for NetBSD, mainly USB Stick cookbooks – probably because NetBSD is already modular and "small" enough (<100MB)
- Live CD distributions and USB stick images are now in standard 'make release' on FreeBSD as of 7.x
- Search for lists like **bengross.com/smallunix/** for small unix distributions
- Join **lists.freebsd.org/pipermail/freebsd-embedded/**
- Read hubertf's NetBSD blog at **www.feyrer.de/NetBSD/bx/blosxom.cgi/index.front?-tags=embedded**

Small SW calls for small HW!

- Search for "Embedded Systems" — albeit a misnomer (traditional embedded systems are something different)
- What is (was) PC/104 based HW?
- Advantages and disadvantages of PC/104 based systems

What is PC/104 ?

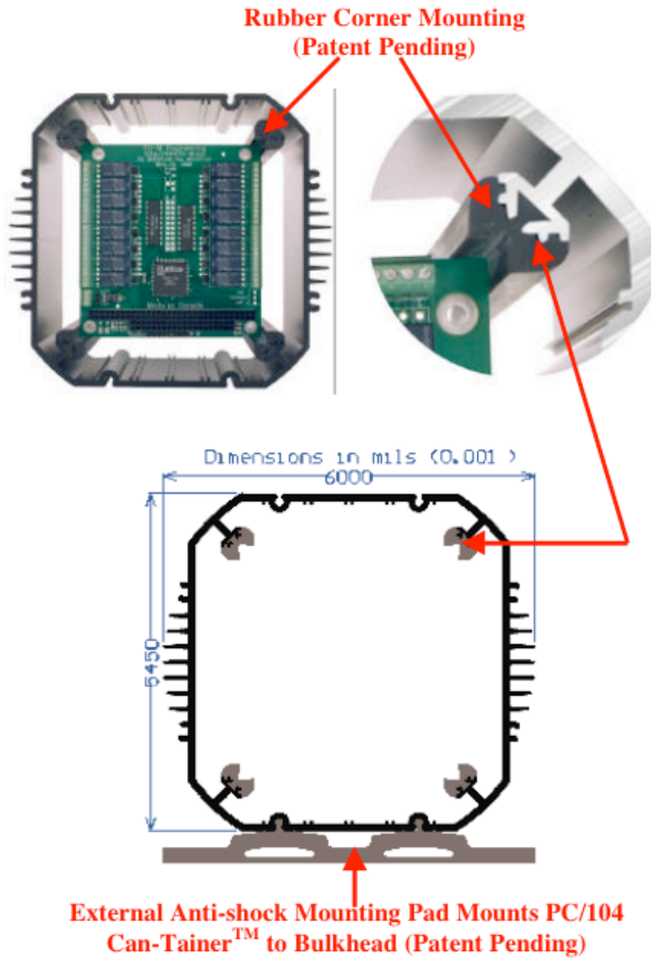
- PC/104 is simply an ISA bus in another, more compact and versatile form factor



- The bus doubles as the structural backbone for the system

- Some good starting points:
  www.smallformfactors.com
  www.controlled.com/pc104faq/
  www.pc104.com/whatis.html

PC/104 "Stacks"

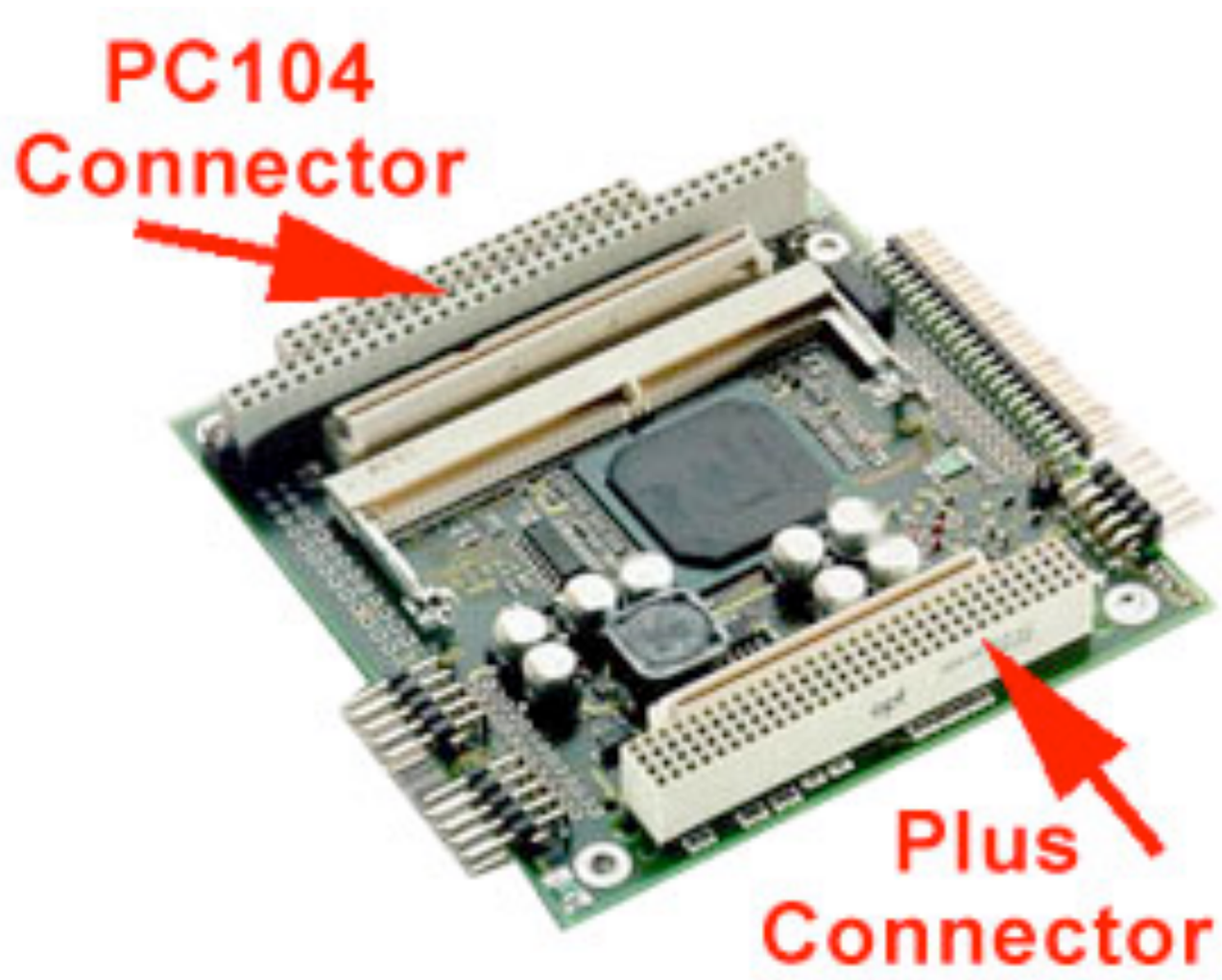


Tri-M Systems PC/104 CAN-TAINER™
PC/104 Container Designed For Hostile Environments

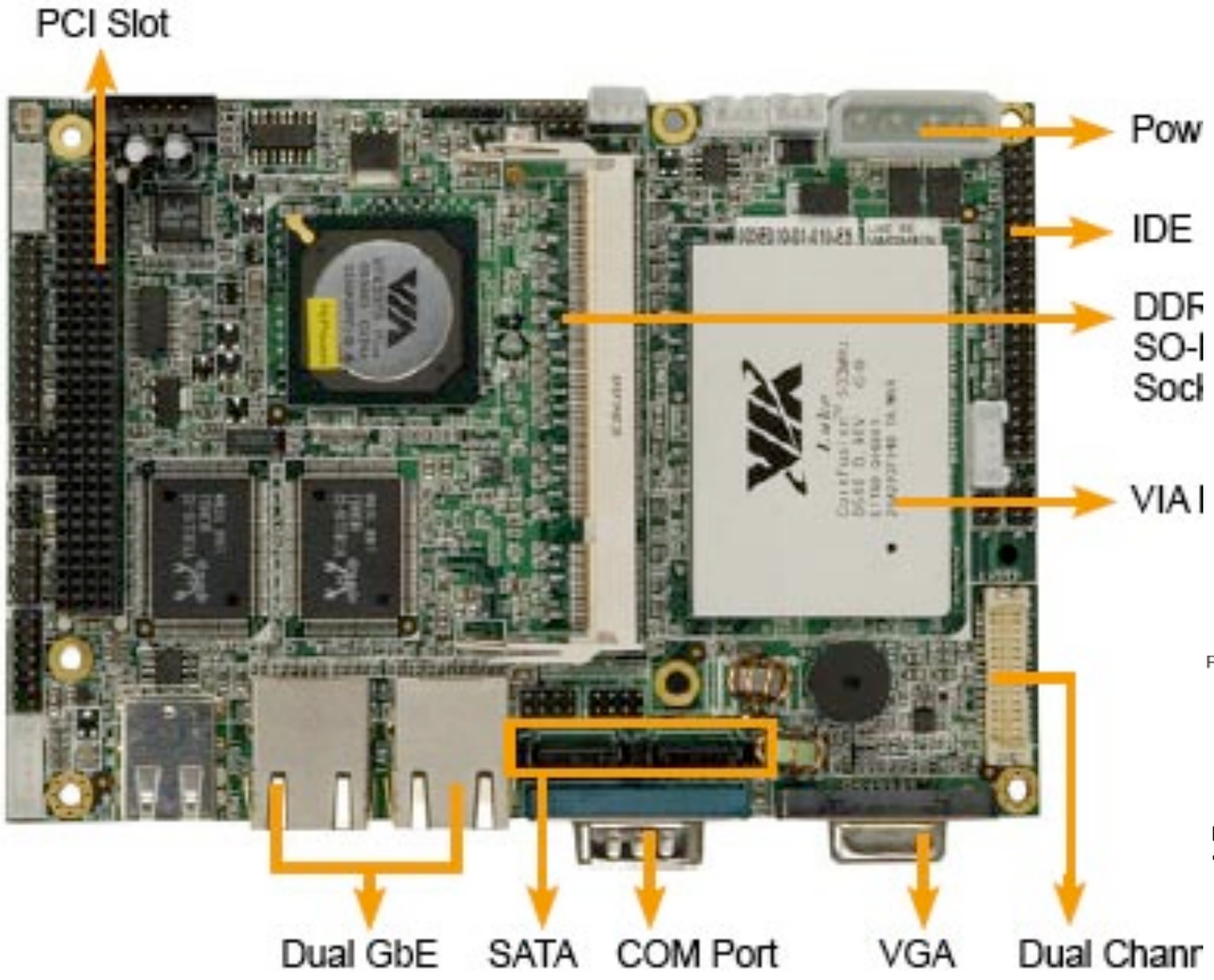
www.dpie.com/pc104/cantainer.html

PC-104 versus PC-104+

- PC-104+ is the PCI bus version of PC/104
- Additional connector (PC/104 - compatible)
- But the modules are often quite expensive!



Single Board Computers (SBC)
3.5 inch "Biscuit PCs"



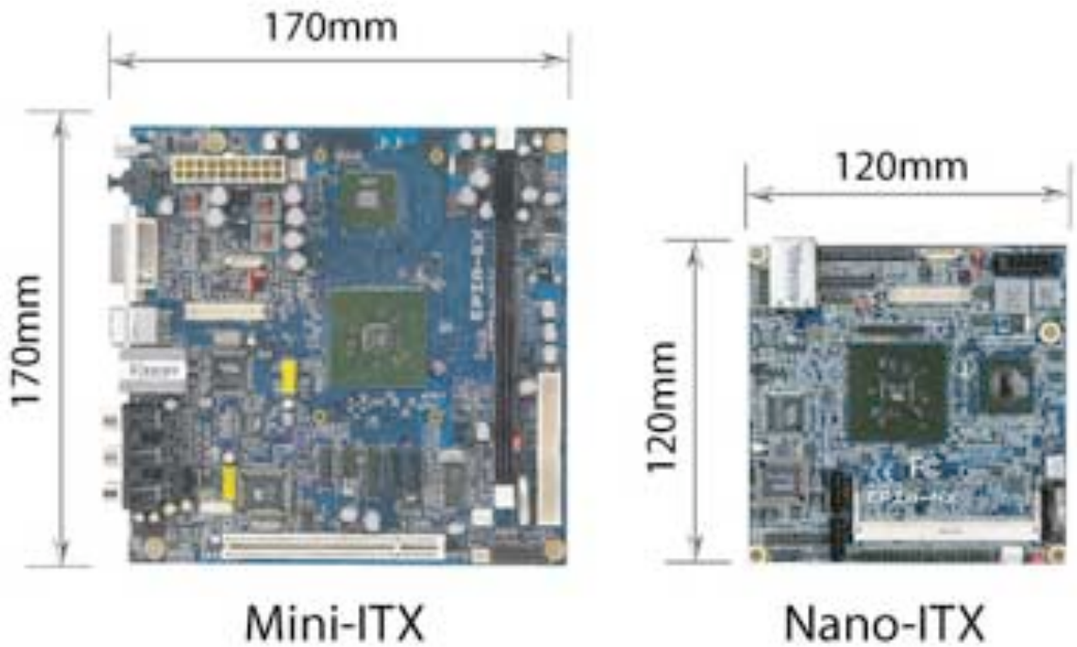
iEi WAFER-LUKE SBC with a fanless, on-board
VIA® LUKE 533MHz or 1GHz CPU, 2 x SATA with RAID 0,1, and JBOD function
support ,VGA, CF Type II socket, PC/104 socket and Dual RTL8110SC GbE chipsets

Advantech, iEi, ... – SBC, PCM-58xx, WAFER, ...

- AMD LX; VIA C3, C5, C7; Intel LV/ULV; Intel Atom
- "Passive" cooling
- AT kbd, VGA/LCD, 2-4 COMs, [Audio]
- ATA HD support
- 1-2 Ethernet [Realtek or Intel], sometimes Gbit
- PC/104 socket, [USB]
- Some vendors known to sell such small x86-based hardware: **www.aaeon.com**, **www.acrosser.com**, **www.advantech.com**, **www.bwi.com**, **www.commell.com.tw**, **www.ieiworld.com**

VIA EPIA Embedded Boards
Mini - ITX Form Factor

For example
VIA EPIA-EN12000EG 1200MHz Mini-ITX Fanless



www.via.com.tw/en/products/mainboards/

Mini - ITX Form Factor

- Intel Atom (single and multicore) low power
- PCIe to support Gbit network and SATA speeds
- Today, Mini-ITX is a commodity available from well known PC motherboard manufacturers like Asus, AsRock, DFI, Gigabyte, MSI, SuperMicro, ...
- Often the power supply or the companion chips require active cooling, so ask yourself:

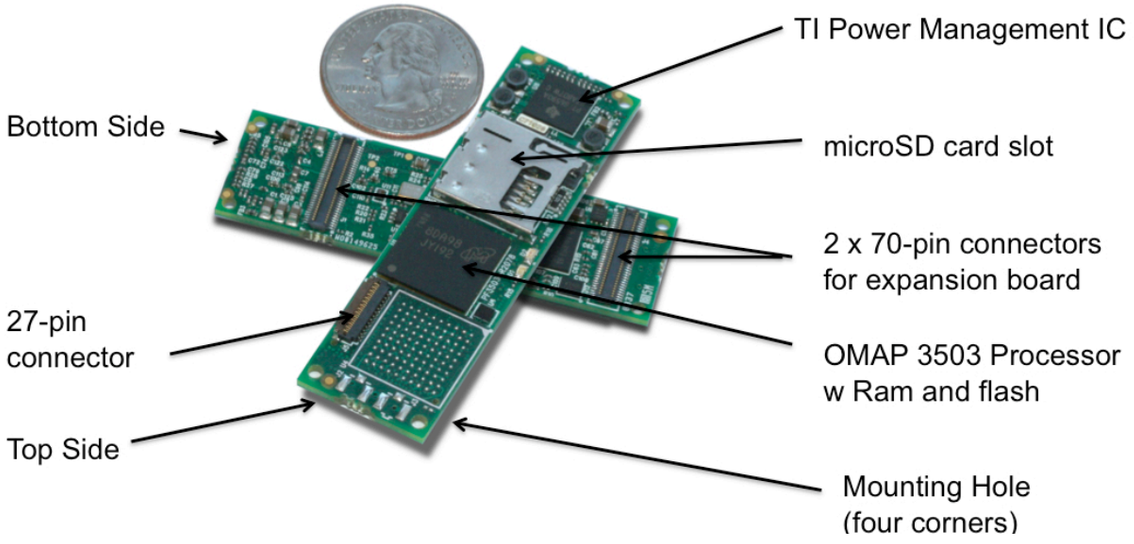
  Will the complete system really be fanless (quiet)?

  Will the system be stable when operated fanless?

One of the Smallest (not x86-based)

"Gumstix" form factor **www.gumstix.com**

www.feyrer.de/NetBSD/blog.html?-tags=gumstix

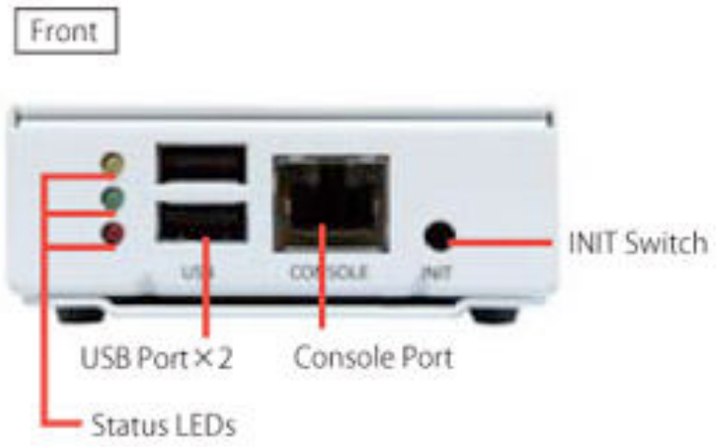


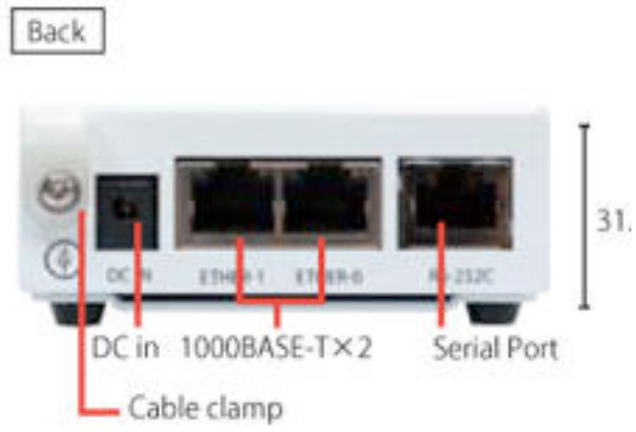
NetBSD on PowerPC

Kiyohara Takashi <kiyohara@netbsd.org> has worked on porting NetBSD to Gumstix, SheevaPlug and Plathome's **openblocks.plathome.com**

OpenBlockS600 (AMCC PowerPC 405EX)

tracker.netbsd.org/pub/NetBSD/misc/kiyohara/tmp/





"The world is changing very fast. Big will not beat small anymore. It will be the fast beating the slow."

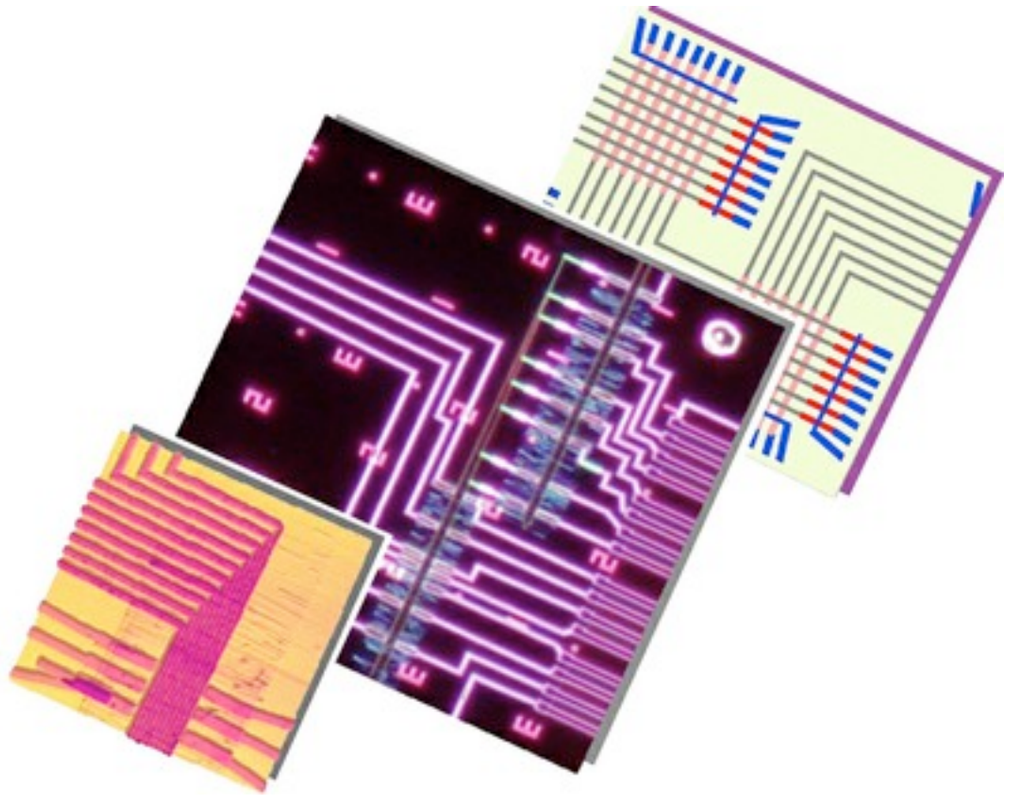
– Rupert Murdoch (Chairman of News Corporation)

Researchers at Harvard and MITRE produce world's first programmable nanoprocessor

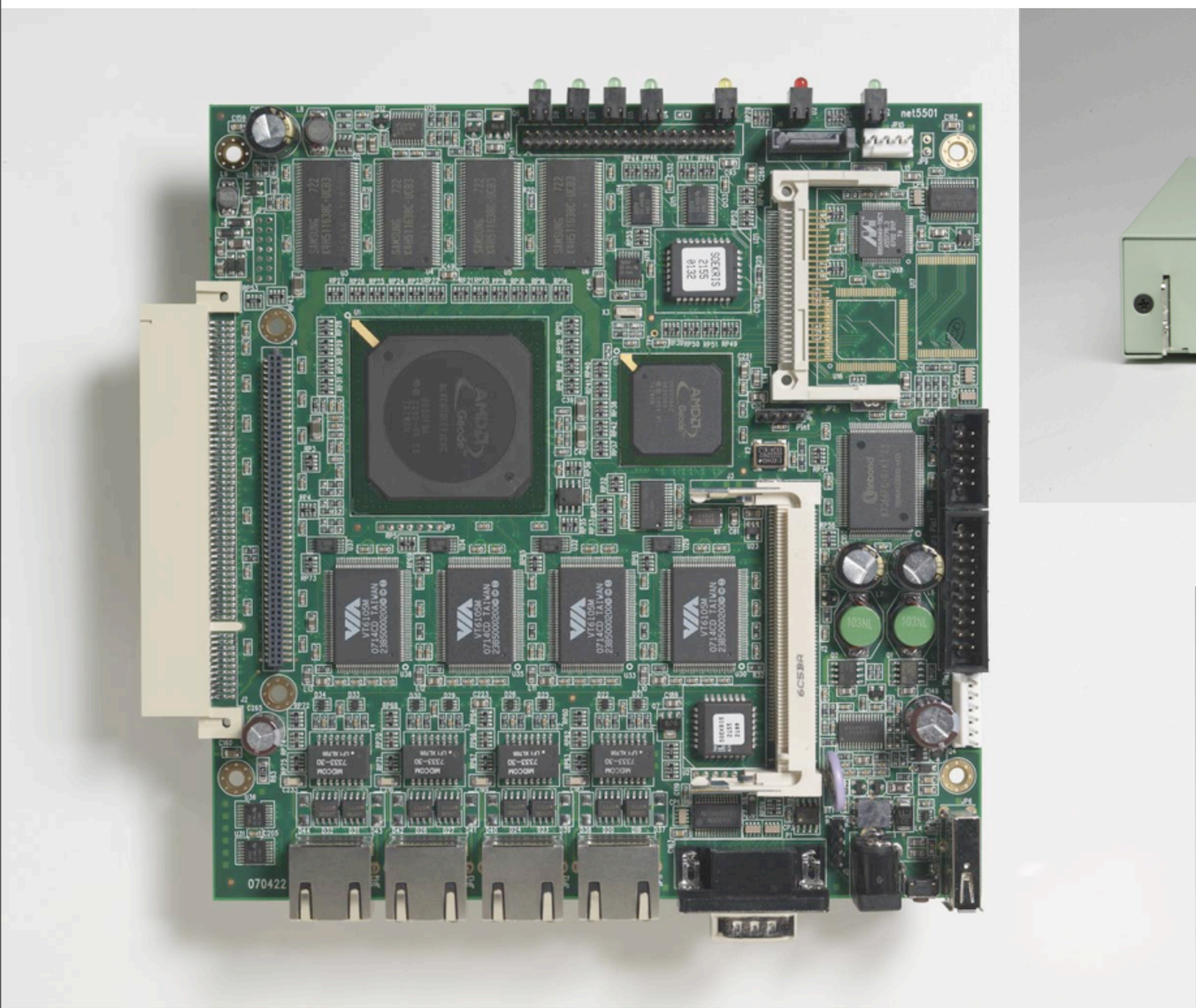
February 9, 2011

Nanowire tiles can perform arithmetic and logical functions and are fully scalable

The versatile, nanoscale circuits are assembled into tiny tile-like nanoprocessors from sets of precisely engineered and fabricated germanium-silicon wires with functional oxide shells, having a total diameter of only 30 nanometers. Shown here are atomic force (left) and optical microscopy (center) images of a programmable nanowire nanoprocessor, and a corresponding schematic (right) of the nanowire circuit architecture.



www.soekris.com



net5501-70

500 Mhz Geode LX CPU, 512 Mbyte DDR-SDRAM, 4 Ethernet, 2 Serial, USB connector, CF socket, 44 pins IDE connector, SATA connector, 1 Mini-PCI socket, 3.3V PCI connector.

www.soekris.com

Date: Tue, 15 Dec 2009 21:19:31 +0100
From: Soren Kristensen <soren@soekris.com>
To: soekris-tech@lists.soekris.com
Subject: Re: [Soekris] New models?
Organization: Soekris Engineering

Hi Everybody,

Maybe it's time to tell a little more.... The net6501 is moving forward and I do expect to have hardware ready in Q1 2010, although I am known to be an optimist :-)

The net6501 will basically be like the other boards, just faster, with more memory and PCI Express expansion.

There will be both a 2 and 4 port gigabit ethernet version, using Intel controllers, where the 2 ports version will be targeting small servers, with up to 4 of them in a 1U case....

And yes, it will be based on the next generation Intel Atom processor, the Pineview platform, in both single and dual core versions and with up to 2 Gbyte DDR2-SDRAM soldered on.

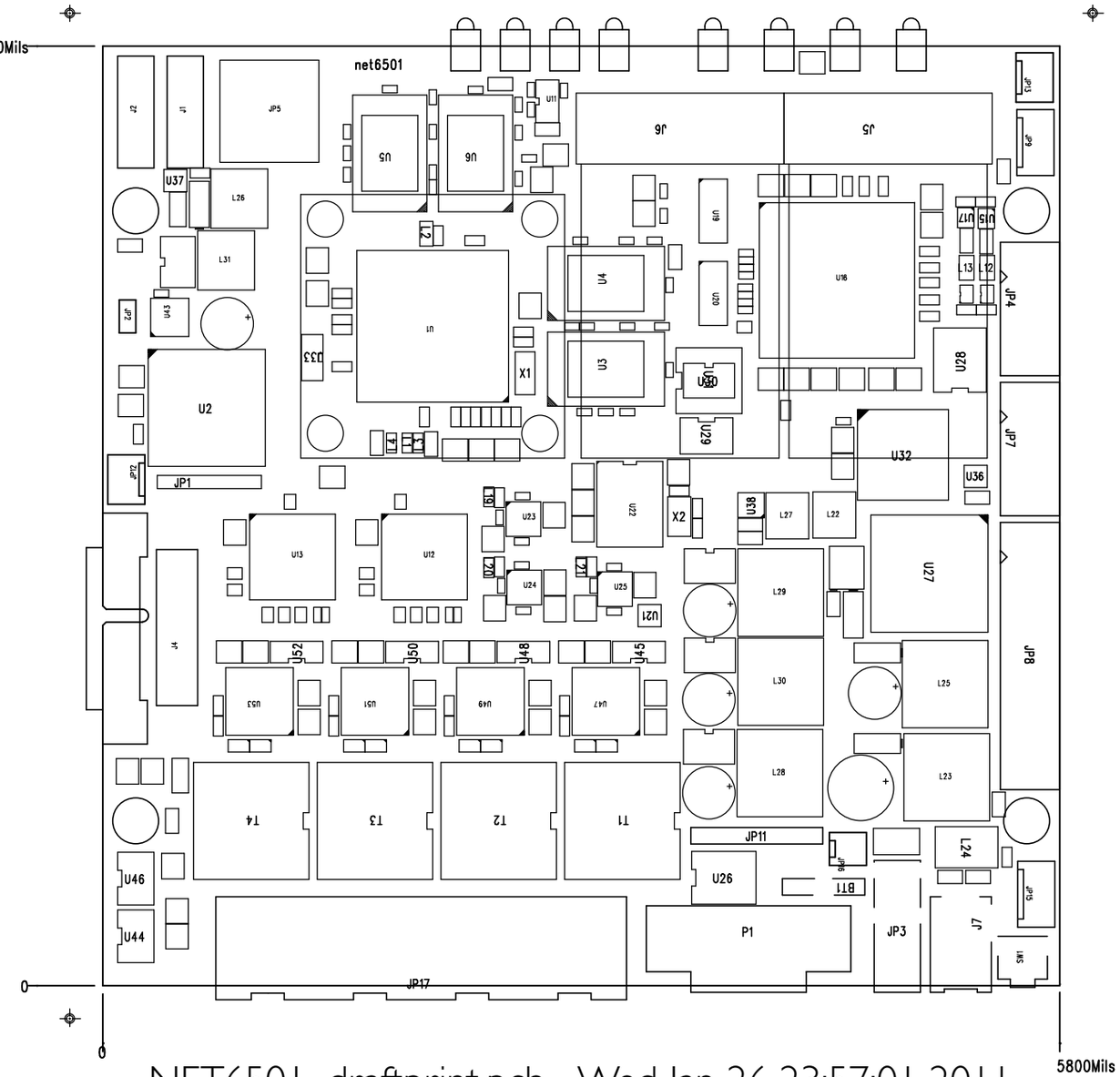
And it will still be low power and high reliability, with passive cooling. Ok, a tiny server with two 2.5" 10K rpm SATA drives will need a small fan....

A new goodie will be onboard NiMH batteri charger/controller.

Best Regards,

Soren Kristensen

CEO & Chief Engineer
Soekris Engineering, Inc.

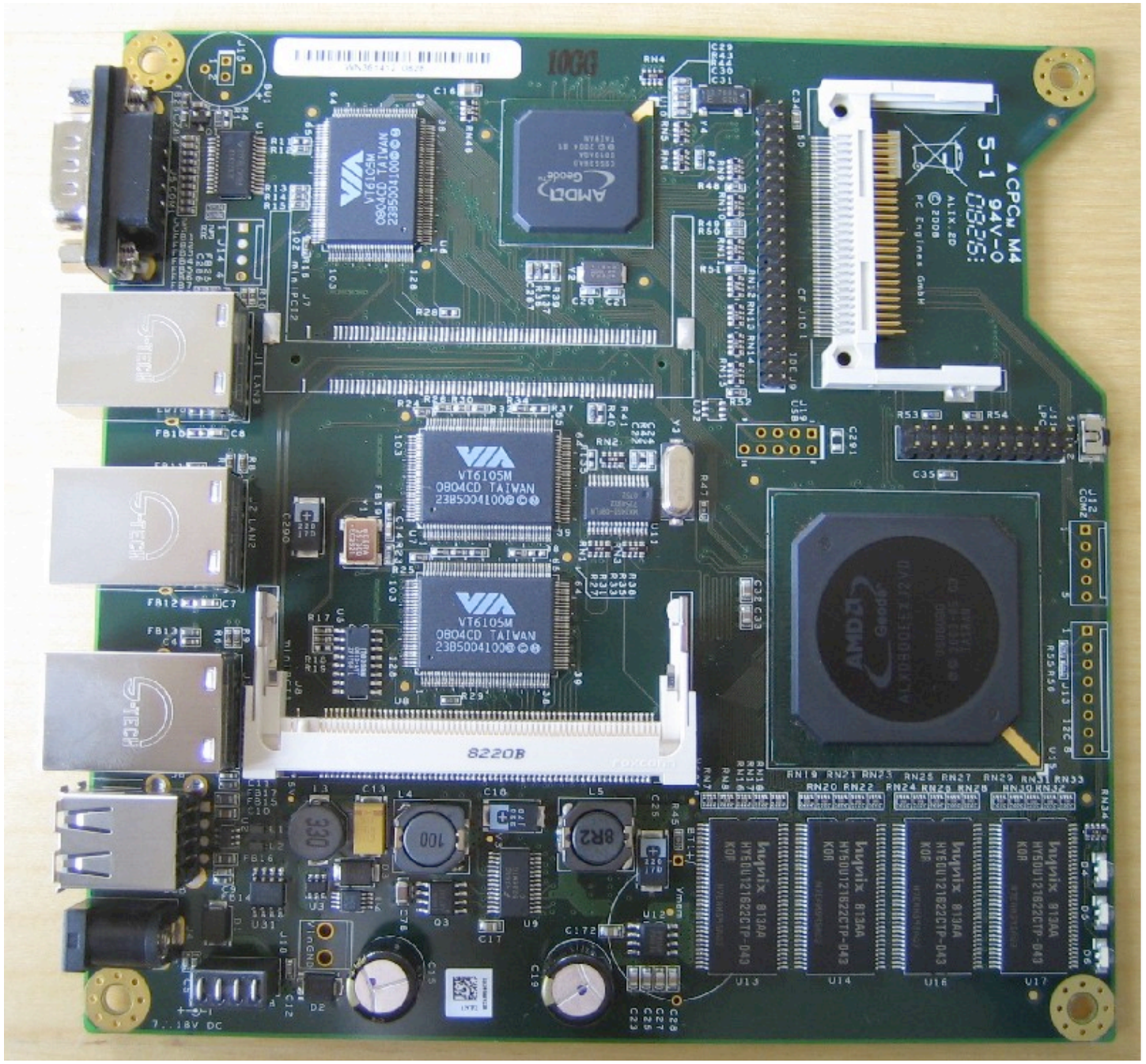


NET6501_draftprint.pcb - Wed Jan 26 23:57:01 2011

net6501

600 Mhz to 1.6 Ghz Intel Atom E6xx Atom single chip processor and EG20T companion chip for PCIe, 512-2GB DDR2-SDRAM, 4 Gbit Intel NIC, 3 x SATA, USB 2.0, 2 x serial, ...

www.pcengines.ch

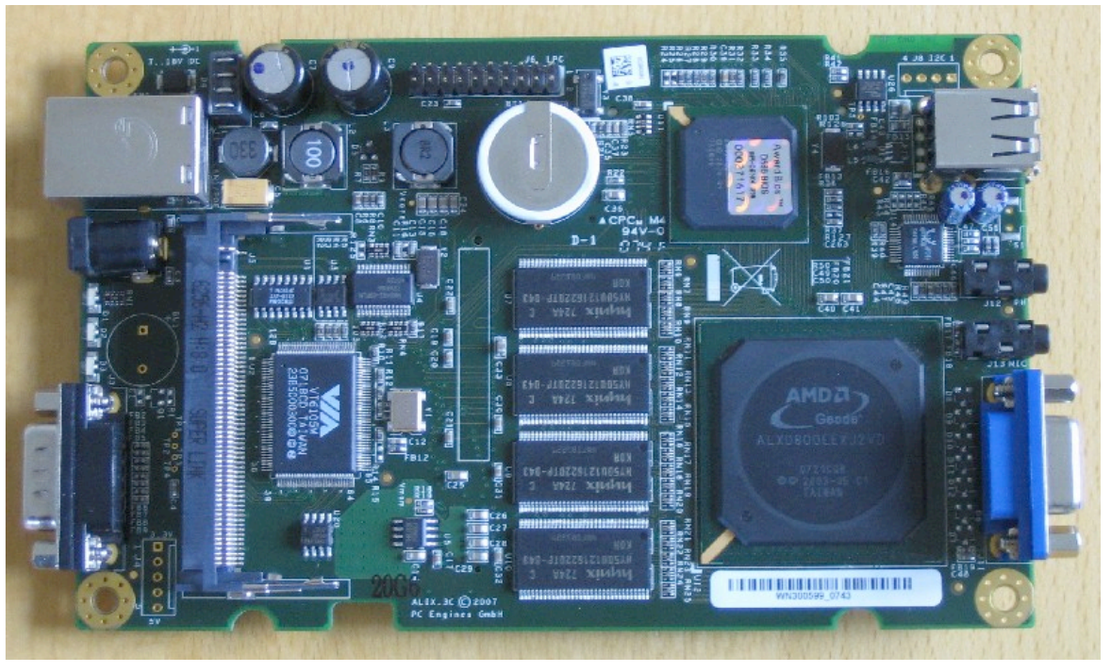


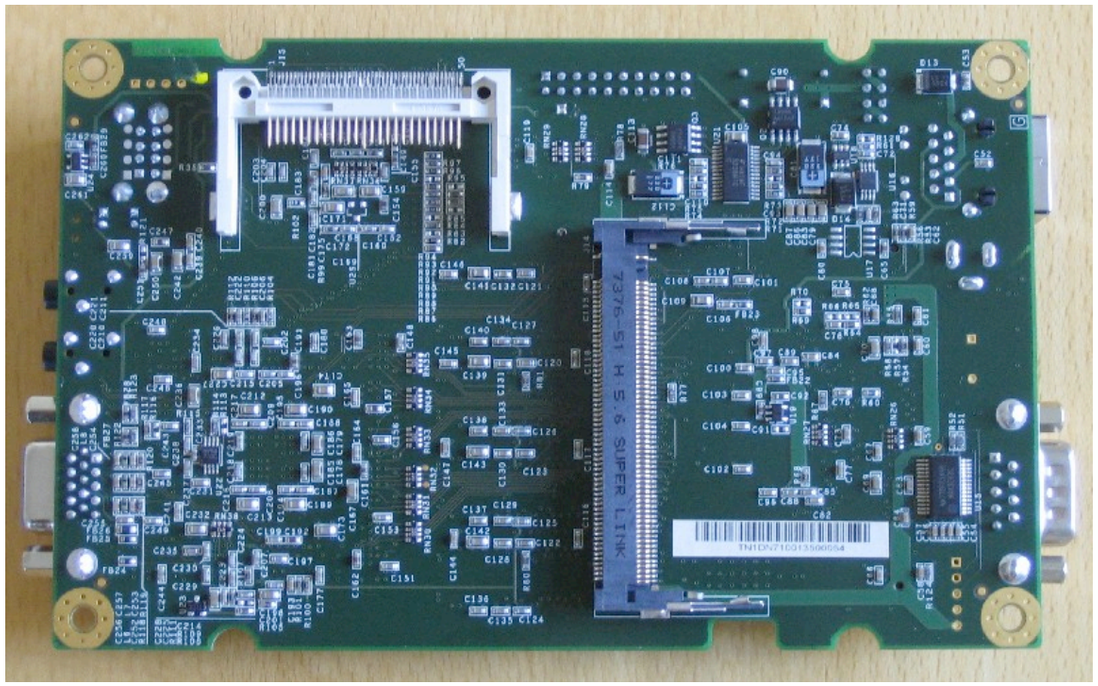
alix2d3

3 LAN / 1 miniPCI / LX800 / 256 MB / USB

- CPU: 500 MHz AMD Geode LX800
- DRAM: 256 MB DDR DRAM
- Storage: CompactFlash socket, 44 pin IDE header
- Power: DC jack or passive POE, min. 7V to max. 20V
- Three front panel LEDs, pushbutton
- Expansion: 1 miniPCI slot, LPC bus
- Connectivity: 3 Ethernet channels (Via VT6105M 10/100)
- I/O: DB9 serial port, dual USB port
- Board size: 6 x 6" (152.4 x 152.4 mm)
- Firmware: tinyBIOS

PC Engines: Even smaller!





alix3d3 = 1 LAN / 2 miniPCI / LX800 / 256 MB / USB / VGA / audio - designed for thin clients or networked audio players.

Default Serial BIOS parameters for PC Engines and Soekris

- PC Engines factory default parameters

`38400 8N1`

Type “S” at power-on for BIOS

- Soekris factory default parameters

`19200 8N1`

Type “Control-P” at power-on for BIOS

Default Serial BIOS parameters for PC Engines and Soekris

- PC Engines factory default parameters

38400 8N1

Type "S" at power-on for BIOS

- Soekris factory default parameters

19200 8N1

Type "Control-P" at power-on for BIOS

Compact Flash (CF)

- Most are good for a million write/erase cycles
  CF/SD Performance Database at
  www.robgalbraith.com/bins/multi_page.asp?cid=6007
- Superblocks are saved often so a million writes are not enough (**`noatime`** option to mount read-write)
- Best is to mount read-only - never a **`fsck`** again!
- Mounting CF read-only is easy on FreeBSD:

```
touch /etc/diskless
/conf/base/... for /etc/rc.initdiskless
```

- This same script also works on NetBSD!

Mount CF read-only, and then mount RAMdisk for read-write areas

On FreeBSD /dev is a devfs, i.e. 'writable'

For others:

```
/sbin/mdmfs -S -i 4096 -s size -M md mount_point
```

When /dev/console is missing: NetBSD creates a new /dev on a RAMdisk using /dev/MAKEDEV

For others:

```
/sbin/mount_mfs -i 4096 -s size swap mount_point
```

How to Install onto a CF system without a CD or Floppy drive, video console, nor keyboard?

- First install and setup the OS on (laptop) harddisk then install from there onto CF for target system
- Essential: **PCMCIA** CF/IDE adapter (aka CF/ATA adapter) to initialize the CF via the laptop
- USB CF Adapters do not work well in all cases because they often assume a non-BIOS geometry (not corresponding to real C/H/S addressing). This results in the feared "no operating system on disk" message when booting the CF on the target system

How to Install onto a CF system without a CD or Floppy drive, video console, nor keyboard?

Installation via PXE netboot !

BIOS and NIC needs to support Intel® PXE support

"FreeBSD Jumpstart Guide"

jdc.parodius.com/freebsd/pxeboot_serial_install.html

people.freebsd.org/~alfred/pxe/en_US.ISO8859-1/articles/pxe/article.html

Diskless NetBSD HOW-TO

www.netbsd.org/docs/network/netboot/intro.i386.html

bsdsupport.org/2007/01/netbsd-pxe-boot-install-without-nfs/

Setting Serial Console

Serial console NetBSD:

```
# installboot -v -m i386 -o
timeout=3,console=com0,speed=38400 -t
ffs /dev/rwd1a /usr/mdec/bootxx_ffsv1
```

Serial console FreeBSD:

```
$ cat /boot.config
-h -S38400
```

Disable AT Keyboard, no video:

```
$ cat /boot/loader.conf
hint.atkbdc.0.disabled="1"
hint.sc.0.disabled="1"
hint.vga.0.disabled="1"
```

FreeBSD Kernel tuning GEODE and "SOEKRIS"

For older Geode (pre AMD Geode-LX) CPUs

```
options CPU_GEODE
options CPU_SOEKRIS
```

- Creates watchdog device (**`/dev/fido`**) on Advantech, PC Engines, and Soekris
- Creates LED devices (**`/dev/led/*`**) on PC Engines and Soekris

– see **`/usr/src/sys/i386/i386/geode.c`**

Kernel Configuration for Crypto Accelerators

Enable in-kernel cryptography (hardware or software)

```
pseudo-device crypto
pseudo-device swcrypto
```

Geode LX Security Block crypto accelerator (i.e., PC Engines ALIX, Soekris net5501)

```
glxsb* at pci?
```

Hifn 7751, 7951, 7811, 7955, and 7956 chipsets (i.e. Soekris vpn1211)

```
hifn* at pci? dev ? function ?
```

Crypto and RNG in VIA C3, C7 and Eden processors (i.e. VIA EPIA Mini-ITX)

```
options VIA_PADLOCK
```

Kernel Configuration for Crypto Accelerators

Enable in-kernel cryptography (hardware or software)

```
device crypto
device cryptodev
```

Geode LX Security Block crypto accelerator (i.e., PC Engines ALIX, Soekris net5501)

```
device glxsb
```

Hifn 7751, 7951, 7811, 7955, and 7956 chipsets (i.e. Soekris vpn1211)

```
device hifn
```

Crypto and RNG in VIA C3, C7 and Eden processors (i.e. VIA EPIA Mini-ITX)

```
device padlock
```

Kernel Configuration for Crypto Accelerators

Enable in-kernel cryptography (hardware or software)

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```
glxsb* at pci?
```

```
device glxsb
```

Hifn 7751, 7951, 7811, 7955, and 7956 chipsets (i.e. Soekris vpn1211)

```
hifn* at pci? dev ? function ?
```

```
device hifn
```

Crypto and RNG in VIA C3, C7 and Eden processors (i.e. VIA EPIA Mini-ITX)

```
options VIA_PADLOCK
```

```
device padlock
```

Building kernel and userland

See also **http://www.netbsd.org/docs/updating.html**

```
$ cd /usr/src

$ cvs up -Pd

$ ./build.sh -O ../obj -T ../tools tools

$ ./build.sh -O ../obj -T ../tools
kernel=MYKERNEL
```

The kernel configuration file is in

/usr/src/sys/arch/i386/conf/MYKERNEL

Note that these userland- and kernel- compilation steps do not require superuser privileges

Installing kernel and userland

Installation does require superuser privileges:

```
$ su

# mv /netbsd /netbsd.old
# mv /usr/obj/sys/arch/i386/compile/MYKERNEL/netbsd /
# shutdown -r now
```

Test if new kernel is working, otherwise boot /netbsd.old from boot loader

```
$ cd /usr/src
$ su
# ./build.sh -O ../obj -T ../tools -U install=/
```

Building and installing kernel

http://www.freebsd.org/doc/handbook/kernelconfig-building.html

```
# cd /usr/src
# cvs up -Pd
```

See **http://www.freebsd.org/doc/handbook/anoncvs.html**

on how to keep current on a FreeBSD branch via CVS

```
# make buildkernel KERNCONF=MYKERNEL
# make installkernel
```

The kernel configuration file is in

/usr/src/sys/i386/conf/MYKERNEL

Building and installing world

```
# make buildworld
```

```
# reboot
```

Test if new kernel works, otherwise reboot with

`/boot/kernel.old/kernel` from loader on the console

```
# mergemaster -p
```

```
# make installworld
```

```
# mergemaster
```

This should be done in single user if the machine would otherwise be busy

Summary First Half

- ☑ Many all-in-one FreeBSD images for "small platforms" exist (minimal install of FreeBSD is about 130MB)
- ☑ NetBSD minimal *is* small enough for small today's small platforms (base.tgz + etc.tgz sets requires 80 MB)
- ☑ Small Hardware
  Look for embedded systems, fanless systems, and don't be afraid of PC/104 - it's just an ISA bus
- ☑ Serial consoles, RAMdisks, and read-only filesystems on CF are your friends
- ☑ Build custom kernels on a fast "build" system to take full advantage of HW features (crypto accelerators)

Outlook Second Half

1. A closer look at how *BSD boots/installs
   - The install CD
   - The boot sequence
   - Building crunched binaries
2. The missing bits needed for building a networked maintenance RAMdisk
3. Some details of building and installing the maintenance RAMdisk
4. Using a "RAMdisk maintenance environment" to install/upgrade OS (demonstration)

Booting FreeBSD (3 stage boot)

www.freebsd.org/doc/en_US.ISO8859-1/books/handbook/boot.html
www.freebsd.org/doc/en_US.ISO8859-1/books/arch-handbook/boot.html

BIOS POST "executes" first 446 bytes of sector 0 – this is a MBR, i.e. the **boot0** or a **boot0sio** program plus the disk slice table (this is also where the dreaded 'no operating system on disk' or Fn-key loop can happen). The "active" PC slice is chosen and its first sector, i.e., the first 512 bytes (**boot1**) in that slice are executed.

fdisk -B /dev/ad0
or
boot0cfg /dev/ad0

(1) **boot1** (512 bytes) executes **boot2** also in that active PC slice

bsdlabel -B /dev/ad0s1

(2) **boot2** understands the FreeBSD disk label as well as the FreeBSD unix file system so it can load **/boot/loader** from that slice

```
>>FreeBSD/i386 BOOT
Default: 1:ad(1,a)/boot/loader
boot:
```

(3) **/boot/loader** sets **kenv(1)** variables, loads **kernel** and modules, and finally boots FreeBSD

```
BTX loader 1.0 BTX version is 1.01
...
Hit [Enter] to boot immediately, or any other key ...
OK
```

/boot/loader.rc
/boot/loader.conf

fdisk & bsdlabel vs gpart

GEOM is the "new" (2004) I/O abstraction for FreeBSD, see
www.bsdcan.org/2004/papers/geom-tutorial.pdf
it's modular, stackable, POLA, DWIM, policy-free, by phk@

GEOM gives us all the good things like
Disk Striping, Mirroring, RAID, Encryption, ...

GEOM also gives us transitional grief with **fdisk** and **disklabel** versus **gpart**
a workaround **sysctl** variable **kern.geom.debugflags=16** (the '*foot-shooting*' bit)
is sometimes required between FreeBSD 7.x and early 8.x to run the "old" commands
because GEOM now tastes the labels with GEOM_PART_BSD and not (legacy) GEOM_BSD
http://svn.freebsd.org/viewvc/base?view=revision&revision=186240

Worse, sometimes GENERIC kernel complains profusely as
GEOM_PART_BSD tastes the label saying "geometry doesn't match label"
http://lists.freebsd.org/pipermail/freebsd-geom/2010-January/003858.html
http://forums.freebsd.org/archive/index.php/t-9105.html
http://forum.nginx.org/read.php?23,155764

"Fixes":

On nbsd before installing fbsd: **dd if=/dev/zero of=/dev/wd0 bs=512 count=1024**
On FreeBSD: **fdisk -a -1 ...** becomes **gpart set -a active -i 1 ...**

/boot/loader

The FreeBSD **loader(8)** is a statically linked standalone executable providing a Forth interpreter and a set of builtin commands to assist in pre-configuration and recovery

'The main drive behind these commands is user-friendliness'

Today, the main reason for **/boot/loader**'s existence is to set all the kernel environment variables (**kenv**), present a boot menu, and (possibly) a splash image

Some example **/boot/loader** commands

- **help**
- **set**
- **more**
- **words**
- **show**
- **ls**
- **1000 ms**
- **include**

Booting NetBSD (2 stage boot)

www.netbsd.org/docs/guide/en/chap-misc.html#chap-misc-bootmanager
www.netbsd.org/docs/guide/en/chap-inst.html#chap-inst-install-geometry

BIOS POST "executes" first 446 bytes of sector 0 – this is a MBR, NetBSD has a few

- Normal boot code **`/usr/mdec/mbr`**
  - Like DOS: just boot from active partition
- Bootselector **`/usr/mdec/mbr_bootsel`**
  - Choice between partitions
- Extended Bootselector **`/usr/mdec/mbr_ext`**
  - Load NetBSD from an extended partition
- Serial Bootselector **`/usr/mdec/mbr_com0`**
  - Same as mbr_ext but will read and write from the first **serial** port.
  - It assumes that the BIOS has initialized the baud rate.
- Serial Bootselector **`/usr/mdec/mbr_com0_9600`**
  - Same as as mbr_com0, additionally it initializes the serial port to 9600 bps.

```
fdisk -B /dev/wd0
```

or

```
mbrlabel /dev/wd0
```

NetBSD bootstrap consists of two parts: a *primary* bootstrap written into the disklabel area of the file system by **`installboot`**, and a *secondary* bootstrap that resides as an ordinary file in the file system.

```
cp /usr/mdec/boot /boot
installboot -v -o timeout=5 /dev/rwd0a /usr/mdec/bootxx_ffsv1
```

FreeBSD Install CD

```
$ cat /cdrom/boot/loader.conf
mfsroot_load="YES"
mfsroot_type="mfs_root"
mfsroot_name="/boot/mfsroot"

$ zcat /cdrom/boot/mfsroot > /tmp/m
# mdconfig -a -t vnode -f /tmp/m
md0
# mount /dev/md0 /mnt
```

```
$ file /mnt/stand/*

/mnt/stand/-sh:                 ELF 32-bit LSB executable, Intel
80386, version 1 (FreeBSD), for FreeBSD 7.1, statically
linked, FreeBSD-style, stripped

...

/mnt/stand/zcat:                ELF 32-bit LSB executable, Intel
80386, version 1 (FreeBSD), for FreeBSD 7.1, statically
linked, FreeBSD-style, stripped
```

NetBSD Install CD

```
$ cat boot.cfg
menu=Install NetBSD:load /miniroot.kmod;boot netbsd
menu=Install NetBSD (no ACPI):load /miniroot.kmod;boot netbsd -2
menu=Install NetBSD (no ACPI, no SMP):load /miniroot.kmod;boot
netbsd -12
menu=Drop to boot prompt:prompt

$ ls -l miniroot.kmod
-rw-r--r--  1 root  wheel  1019259 Feb  3 02:33 miniroot.kmod

$ file miniroot.kmod
/mnt/miniroot.kmod: gzip compressed data, from Unix, last
modified: Tue Feb  3 02:26:42 2009, max compression

$  ls -l netbsd
-rw-r--r--  1 root  wheel  5046737 Feb  3 02:33 netbsd
$ file netbsd
netbsd: gzip compressed data, was "netbsd-GENERIC", from Unix, max
compression
```

crunchgen

Makes one statically linked binary for a set of programs (/rescue)

Toy example

i. **`crunchgen pls.conf`**

ii. **`make -f pls.mk`**

iii. **`./pls`**

```
srcdirs /usr/src/bin
progs ls
libs -lncurses -lutil
progs ps
libs -lm -lkvm
```

Compare sizes of **`/bin/ps`**, **`/bin/ls`**, **`./pls`**

Build a Maintenance RAMdisk
A Straightforward Plan

i. Make a list of commands we need for system installation via a SSH session

ii. Use crunchgen to combine all commands into one "static" binary

iii. Craft a RAMdisk filesystem image which configures network and starts SSH daemon

iv. Boot into this RAMdisk image like the Install CD

http://www.bsdnewsletter.com/2003/09/Features102.html

described this method for building "tiny systems" NetBSD in 2003

Yet not so easy, because

- We specifically want some programs on RAMdisk which turn out to be *crunchgen-unfriendly:*
  - SSH doesn't crunch "out of the box"
    - By default, SSH links in far too many libraries
    - Programs based on GEOM classes require the runtime loader

- Network parameters should be text-file editable, and the RAMdisk md_image should stay generic

Crunching SSHD fails

- This **`crunchgen.conf`** fragment fails with straightforward configuration:

```
buildopts -DNO_KERBEROS
buildopts -DNO_PAM
srcdirs /usr/src/secure/usr.bin
srcdirs /usr/src/secure/usr.sbin
progs scp ssh sshd
libs -lssh -lutil -lz -lcrypt
libs -lcrypto -lmd
```

link phase wants **`libwrap.a`** and **`libpam.a`** routines

Crunching SSHD fixed

- Change hard-coded **`#defines`** directly in **`/usr/src/crypto/openssh/config.h`**

```
#undef LIBWRAP
#undef USE_PAM
#undef HAVE_LIBPAM
#undef HAVE_PAM_GETENVLIST
#undef HAVE_SECURITY_PAM_APPL_H
#undef XAUTH_PATH
```

NetBSD crunches using Makefile technology – what else?

`Makefile` essentials

```
...

IMAGE=          ramdisk-${BOOTMODEL}.fs
IMAGESIZE=      5000k

.include "${NETBSDSRCDIR}/distrib/common/Makefile.distrib"

CRUNCHBIN=      ramdiskbin
LISTS=          ${.CURDIR}/list
MTREECONF=      ${DISTRIBDIR}/common/mtree.common

PARSELISTENV+=  CUSTOM_SSHD=${.CURDIR}/custom_sshd

# This propogates through to the link of ramdiskbin
CRUNCHENV += MKSKEY=no MKWRAP=no MKPAM=no MKKERBEROS=no MKSHARE=no RELEASE_CRUNCH=yes

...

.include "${DISTRIBDIR}/common/Makefile.crunch"
.include "${DISTRIBDIR}/common/Makefile.image"

MDSETTARGETS= \
        ${NETBSDOBJDIR}/sys/arch/i386/compile/INSTALL_FLOPPY/netbsd ramdisk-custom.fs netbsd-RAMDISK

.include "${DISTRIBDIR}/common/Makefile.mdset"

.include <bsd.prog.mk>
```

and a "`list`" file (almost like a `crunchgen.conf`)

Crunching SSHD fixed

Simply remove offending stuff from **/usr/src/usr.bin/ssh/sshd/Makefile**

```
$ cat custom_sshd/Makefile

.include <bsd.own.mk>

SSHDIST?= ${NETBSDSRCDIR}/crypto/dist/ssh

.PATH: ${SSHDIST}

CPPFLAGS+=-I${SSHDIST} -DHAVE_LOGIN_CAP -DHAVE_MMAP -DHAVE_OPENPTY

LDADD+= -lssh -lcrypto -lcrypt -lz -lutil
DPADD+= ${LIBSSH} ${LIBCRYPTO} ${LIBCRYPT} ${LIBZ} ${LIBUTIL}

CPPFLAGS+=-DSUPPORT_UTMP -DSUPPORT_UTMPX

PROG=   sshd
MAN=    sshd.8

SRCS=   sshd.c auth-rhosts.c auth-passwd.c auth-rsa.c auth-rh-rsa.c \
        sshpty.c sshlogin.c servconf.c serverloop.c uidswap.c \
        auth.c auth1.c auth2.c auth-options.c session.c \
        auth-chall.c auth2-chall.c groupaccess.c \
        auth-skey.c auth-bsdauth.c auth2-hostbased.c auth2-kbdint.c \
        auth2-none.c auth2-passwd.c auth2-pubkey.c \
        monitor_mm.c monitor.c monitor_wrap.c \
        kexdhs.c kexgexs.c

.include <bsd.prog.mk>
```

GEOM and ZFS use **`dlopen()`**

The GEOM and ZFS commands use dlopen() to load classes from **`/lib/geom`** dynamically

`geom(4), gconcat(8), geli(8), glabel(8), gmirror(8), gnop(8), graid3(8), gshsec(8), gstripe(8), gvirstor(8), zfs(1M), zpool(1M)`

... yet it is exactly these commands – among others – that we need most in a maintenance environment!

“Mostly static” linking

Include **`rtld(1)`** in RAMdisk:

```
/libexec/ld-elf.so.1
```

then, for GEOM classes link dynamically:

```
ldd /lib/geom/*.so
/lib/geom/geom_concat.so
/lib/geom/geom_eli.so
        libmd.so.3 => /lib/libmd.so.3 (0x2815a000)
        libcrypto.so.4 => /lib/libcrypto.so.4 (0x28168000)
/lib/geom/geom_label.so
/lib/geom/geom_mirror.so
        libmd.so.3 => /lib/libmd.so.3 (0x28155000)
/lib/geom/geom_nop.so
/lib/geom/geom_raid3.so
        libmd.so.3 => /lib/libmd.so.3 (0x28154000)
/lib/geom/geom_shsec.so
/lib/geom/geom_stripe.so
```

`crunchgen(1)` with a twist

Linking "mostly static" from **`man crunchgen(1)`**

`libs_so libspec ...`

A list of library specifications to be dynamically linked in the crunched binary. These libraries will need to be made available via the run-time link-editor **`rtld(1)`** when the component program that requires them is executed from the crunched binary. Multiple **`libs_so`** lines can be specified.

```
$ ls -RF lib libexec
lib:
geom/                libgeom.so.4     libncurses.so.7    libutil.so.7
libbsdxml.so.3       libkvm.so.4      libnvpair.so.1     libuutil.so.1
libc.so.7            libm.so.5        libsbuf.so.4       libz.so.4
libcrypto.so.5       libmd.so.4       libufs.so.4        libzfs.so.1

lib/geom:
geom_cache.so        geom_mirror.so         geom_shsec.so
geom_concat.so       geom_multipath.so      geom_stripe.so
geom_eli.so          geom_nop.so            geom_virstor.so
geom_journal.so      geom_part.so
geom_label.so        geom_raid3.so

libexec:
ld-elf.so.1*
```

What's on the RAMdisk ?

```
-sh
[
cat
chflags
chgrp
chmod
chown
chroot

cp
date

df

du

expr

hostname

kill

link
ln
ls

mkdir

mv

ps
pwd

realpath

rm
rmdir

sh
sleep

stty

test
touch
tset

unlink
```

Basics on RAMdisk

```
-sh
[                 du                                mkdir
                                                                  sh
                                                                  sleep
                  expr
                                   hostname
                                                                  stty
cat               init
chflags                                             mv
chgrp
chmod             kenv
chown             kill
chroot
                                                    ps
cp                                                  pwd           test
date                                                              touch
                                   ldconfig         realpath      tset
df                                 link
                                   ln
                                   ls                             unlink
                                                    rm
                                                    rmdir
```

SysAdmin on RAMdisk

```
atacontrol
badsect          dumpfs                                  mknod
boot0cfg                                                 mount
bsdlabel                                                 mount_cd9660
                                                         mount_devfs
                                                         mount_fdescfs
                 fastboot        halt                    mount_linprocfs
                 fasthalt
camcontrol       fdisk                                   mount_procfs
                 ffsinfo                                 mount_std
                 fsck                                                    swapctl
                 fsck_4.2bsd                             newfs           swapoff
                 fsck_ffs                                                swapon
                 fsck_ufs                                                sync
                 gbde            kldconfig                               sysctl
clri                             kldload
                 geli            kldstat
                                 kldunload
dd
                                                         reboot          tunefs
                                                                         umount

diskinfo                         mdconfig                                zfs
disklabel                        mdmfs                                   zpool
```

Networking on RAMdisk

route

ifconfig

ping

dhclient
dhclient-script

More networking RAMdisk

```
                                                    route

                                                    scp



                                                    slogin
                                                    ssh
                                        mount_nfs   sshd
                    ifconfig

                    ipf
                    ipfw

                                        pfctl
                                        ping


          ggatec
          ggated
dhclient  ggatel
dhclient-script
```

Archiving tools on RAMdisk

rrestore

dump

gunzip
gzcat
gzip

bunzip2
bzcat
bzip2

pax

tar

rdump

restore

zcat

Editors on the RAMdisk

ed
ex

sed

red

and last but not least ...

Requires a (small) **`/usr/share/misc/termcap`**

Only 5306 bytes (not 204798 bytes!) supporting
`vt100, vt220, xterm, screen, ansi, AT386`

Being on RAMdisk, the required **`/var/tmp`** exists

`vi`

Maintenance RAMdisk

```
-sh                 dumpfs              growfs              mount               rrestore
[                   ed                  gshsec              mount_cd9660        scp
atacontrol          env                 gstripe             mount_devfs         sed
badsect             ex                  gunzip              mount_fdescfs       sh
boot0cfg            expr                gvirstor            mount_linprocfs     sleep
bsdlabel            fastboot            gzcat               mount_nfs           slogin
bunzip2             fasthalt            gzip                mount_procfs        ssh
bzcat               fdisk               halt                mount_std           sshd
bzip2               ffsinfo             hostname            mv                  stty
camcontrol          fsck                ifconfig            newfs               styxinstall
cat                 fsck_4.2bsd         init                nex                 swapctl
chflags             fsck_ffs            ipf                 nice                swapoff
chgrp               fsck_ufs            ipfw                nvi                 swapon
chmod               gbde                kenv                nview               sync
chown               gcache              kill                pax                 sysctl
chroot              gconcat             kldconfig           pfctl               tar
clri                geli                kldload             ping                test
cp                  geom                kldstat             ps                  touch
date                ggatec              kldunload           pwd                 tset
dd                  ggated              ldconfig            rdump               tunefs
df                  ggatel              link                realpath            umount
dhclient            gjournal            ln                  reboot              unlink
dhclient-script     glabel              ls                  recoverdisk         vi
diskinfo            gmirror             mdconfig            red                 view
disklabel           gmultipath          mdmfs               restore             zcat
dmesg               gnop                mini_crunch         rm                  zfs
du                  gpart               mkdir               rmdir               zpool
dump                graid3              mknod               route
```

NetBSD 5 custom RAMdisk

```
netbsd-RAMDISK# df -h
Filesystem         Size       Used      Avail %Cap Mounted on
/dev/md0a          4.8M       4.5M       381K  92% /
mfs:16             1.0M        36K       975K   3% /dev

netbsd-RAMDISK# ls /*bin /usr/*
netbsd-RAMDISK# ls /*bin /usr/*
/bin:
-sh         cp          echo        kill        mv          rm          stty
[           date        ed          ln          pax         rmdir       sync
cat         dd          expr        ls          ps          sh          test
chmod       df          hostname    mkdir       pwd         sleep

/sbin:
atactl              dump              mbrlabel          mount_ufs         route
badsect             dump_lfs          mknod             newfs             rrestore
ccdconfig           fdisk             modload           newfs_lfs         scsictl
cgdconfig           fsck              modunload         ping              swapctl
clri                fsck_ffs          mount             raidctl           swapon
dhclient            fsck_lfs          mount_cd9660      rcorder           sysctl
dhclient-script     halt              mount_ffs         rdump             tunefs
disklabel           ifconfig          mount_lfs         rdump_lfs         umount
dkctl               init              mount_mfs         reboot
dmesg               ldconfig          mount_nfs         restore

/usr/bin:
bunzip2     du          gunzip      printf      ssh         tset
bzcat       env         gzcat       scp         ssh-keygen  vi
bzip2       ex          gzip        sed         tar         zcat
chflags     ftp         passwd      slogin      touch

/usr/mdec:
boot                bootxx_ffsv2      mbr_bootsel       mbr_com0_9600
bootxx_ffsv1        mbr               mbr_com0          mbr_ext

/usr/sbin:
chgrp           chroot          installboot  pwd_mkdb       vnconfig
chown           dumpfs          mdconfig     sshd           wiconfig
```

On-disk: 8 MB / Runs in 42 MB

- The boot loader is able to preload *gzip-compressed* RAMdisk images
- Additional on-disk (CF) usage is minimal < 8MB

```
$ du -h k.GENERIC.gz fs.8.2-RAMDISK.gz
3.6M k.GENERIC.gz
4.3M fs.8.2-RAMDISK.gz
```

- In RAM currently defined as 14.0 MB md0

```
# mdconfig -l -u 0
md0     preload   14.0M
```

$ ls -sh netbsd-RAMDISK.gz
6.6M netbsd-RAMDISK.gz

- The boot program is able to load gzip-compressed netbsd kernels containing RAMdisk images

- RAMdisk space usage is negligible on today CF sizes

- Running RAMdisk is currently defined as 5.0 MB filesystem of which 4.5 MB is used

On-disk: 6.6 MB / Runs in 20 MB + 4.5 MB

On-disk: 7.9 MB / Runs in 27 MB + 14 MB

The RAMdisk personality

- The compressed RAMdisk image stays generic
- The key idea is to pass all machine-specific parameters via the kernel environment **`kenv(1)`**
- These can be set in a **`/boot/maint/params`** file which is an editable textfile and is included by the loader
- Those values are read back into RAMdisk user space via **`kenv(1)`** calls

Example personality

```
OK more /boot/maint/params
*** FILE /boot/maint/params BEGIN ***
set maint.ifconfig_sis0="192.168.1.200/24"
set maint.defaultrouter="192.168.1.1"
set maint.domain="mydomain.ch"
set maint.nameservers="192.168.1.1 192.168.1.100"
set maint.sshkey_01a="ssh-dss AAAAB3N..........cZ9"
set maint.sshkey_01b="ucifE5QoUN..(120 chars)..PYik"
...
*** FILE /boot/maint/params END ***


RAMdisk# sed -ne /kenv/p /etc/rc
kenv | sed -ne 's/^maint\.//p' >> /etc/params
```

One way into RAMdisk

By replacing **`/boot/loader.rc`** with:

```
include /boot/loader.4th
start
unload
load /boot/maint/k.CUSTOM
load -t md_image /boot/maint/fs.6.0-STYX
include /boot/maint/params
set vfs.root.mountfrom=ufs:/dev/md0
autoboot 10
```

Booting into RAMdisk

Change **default=1** menu in **/boot.cfg**

```
$ cat /boot.cfg
menu=Boot normally:boot netbsd
menu=Boot single user:boot netbsd -s
menu=Disable ACPI:boot netbsd -2
menu=Disable ACPI and SMP:boot netbsd -12
menu=Drop to boot prompt:prompt
menu=Maintenance RAMdisk:boot netbsd-RAMDISK
default=6
timeout=5
```

The RAMdisk needs to setup networking specific to this machine so that sshd will be accessible remotely.

Booting into RAMdisk

Have single user shell execute /etc/rc from .profile

```
ETCRC_DONE=/.done_etc_rc

if [ ! -e ${ETCRC_DONE} ]
then
        echo "Running /etc/rc autoboot from .profile"
        /bin/sh /etc/rc autoboot && touch ${ETCRC_DONE}
        exit 0
fi
```

Because init is called with “-s” option and thus would otherwise leave machine in single user mode.

Thank you very much for attending this tutorial!

steinmann.com/AsiaBSDCon2011/SmallBSDTutorial.tbz

Q & A