White Paper

BCM63XX/BCM68XX Power Management

This document reviews the regulations published by the European Union on maximum consumption targets for energy-consuming devices and describes how Broadcom® has addressed these regulations in its BCM63XX and BCM68XX line of products for DSL and GPON modems.

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Introduction

With the increased concern of the impact of our energy use on environment and climate, governments in different parts of the world have decided to impose maximum consumption targets for energy-consuming devices. This document reviews the regulations published by the European Union and describes how Broadcom has addressed these in its BCM63XX and BCM68XX line of products for DSL and GPON modems through software changes.

The BCM63XX and BCM68XX line of products offer highly flexible hardware and software. The manufacturers remain free to decide how they implement the desired power-saving features for their products. This document offers a selection of features which Broadcom has tested to comply with the regulations described below.

Regulation Overview

Broadband Equipment Regulations

The European Union has published a *Code of Conduct on Energy Consumption of Broadband Equipment*[1], which will be referred to as "the CoC" in this document. The CoC lists the types of equipment affected by the regulation. It also defines four operational states (Full-power, Low-power, Standby, and Off) and lists the expected state of the interfaces in each operational state. The CoC provides power targets for 2009/2010 and for 2011, broken down per interface. In mid-2010, a new version of the COC will be published, COC version 4, reaffirming the power targets for 2011 and setting new targets for 2012.

While the low-power and full-power modes are well described in the CoC, we need to turn to *European Commission Regulation (EC) No 1275/2008*,[2] also known as the "Lot 6 publication," to better understand the definition of the standby and Off states and to determine the power targets for these states.

Power Supply Regulations

The European Union has also published a *Code of Conduct on Energy Efficiency of External Power Supplies*[3]. This publication defines target efficiency levels for power supplies that are equivalent to Energy Star® Level V[4]. While Broadcom does not manufacture such equipment, power supply efficiency plays an important role in achieving the targets set by the European Code of Conduct for Broadband equipment. For the measurements presented in this document, we use a power supply compliant to Energy Star Level V. Because the efficiency of a power supply varies with the load, we use an efficiency of 82% when the consumed power is below 4 Watts, and 85% when it is above 4 Watts.

1. http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC%20Brodband%20Equipment/Code%20of%20Conduct%20Broadband%20Equipment%20V3%20final.pdf
2. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:EN:PDF
3. http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC_Power_Supplies_Version4-March2009.pdf
4. https://www.energystar.gov/ia/partners/product_specs/eligibility/EPS_Eligibility_Criteria.pdf

Operational States

For testing purposes, the CoC defines the configuration required for making power consumption measurements. Each state requires a different configuration, which is described in this section.

Full-Power State

In the Full-Power state, each port on each interface is active (has a linkup) and is passing 25% of line rate traffic. If voice is available, at least one active call is made on each interface (FXS, DECT). The USB interface is left unconnected.

Low-Power State

In the Low-Power state, the device is idle, and each of the components is in its low-power state. There is no linkup on any of the LAN interfaces, but these remain capable of detecting activity or a new connection. The WAN interface is up, and the device is capable of supporting a low amount of traffic.

It should be noted that for Broadcom-based DSL CPE systems, there is no hard demarcation between the Low-Power state and the Full-Power state. The CPE systems always operate in a Low-Power state, but gradually move towards a Full-Power mode as each interface becomes active, and as the main CPU becomes busy processing packets and applications. This means the Full-Power state is really the last stage of a gradual scale of Low-Power states.

The user does not need to perform any operation to place the CPE in Low-Power state. All transitions between Low-Power and On state are automatically performed by the Broadcom-based hardware and software.

Standby State

The Standby state is only defined at a high level in CoC, but more details are found in the Lot 6 regulation. This state allows the user to automatically switch off the device during periods when no service is needed. The device can be placed in Standby state using a hard method (a button) or a soft method (a programmed schedule on a web page). To comply with the Lot 6 regulation, a CPE is only required to implement either an On/Off switch and/or a Standby button.

Off State

In the Off state, the device is completely turned off and providing no functionality. In this state, only the main AC/DC power supply is consuming a minimum amount of power. Typically, the device is placed in the Off state using a hard method, a button, separate from the standby button.

Power Allowances

The CoC defines the following power allowances for Home Gateways. The relevant rows will be used later in this document.

WAN Interface Allowances

Typically only one of the entries from Table 1 is applicable to a device.

Table 1: CoC WAN Interface Allowances[a]

	Tier 2009/2010: 1.1.2009-31.12.2010		Tier 2011: 1.1.2011-31.12.2011	
Home Gateway Central Functions Plus WAN Interface	**Low-Power State (W)**	**On State (W)**	**Low-Power State (W)**	**On State (W)**
ADSL/ADSL2/ADSL2+	4.2	5.0	2.6	3.8
VDSL2	5.5	7.5	3.5	6.0
Fast Ethernet WAN (100BASE-T)	2.9	4.2	2.5	3.3
Gigabit Ethernet WAN (1000BASE-T)	4.0	7.0	3.2	6.2
Fibre Ptp Ethernet WAN (100/1000BASE-BX or FX)	3.4	7.1	2.9	5.6
GPON	5.0	9.7	4.0	7.7
DOCSIS 2.0	5.5	5.5	3.7	4.6
DOCSIS 3.0	8.0	8.0	6.2	7.1
WiMAX	8.2	11.0	7.7	10.6

a. http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC%20Brodband%20Equipment/Code%20of%20Conduct%20Broadband%20Equipment%20V3%20final.pdf

LAN and Other Interface Allowances

Each applicable row from Table 2 contributes to the allotted power budget for a device.

Table 2: CoC LAN and Other Interface Allowances[a]

	Tier 2009/2010: 1.1.2009-31.12.2010		Tier 2011: 1.1.2011-31.12.2011	
Home Gateway LAN Interfaces and Additional Functionality	**Low-Power State (W)**	**On State (W)**	**Low-Power State (W)**	**On State (W)**
Fast Ethernet switch, up to 4 ports	0.8	2.2	0.6	1.8
1 Fast Ethernet port	0.3	0.5	0.3	0.4
Gigabit Ethernet switch, up to 4 ports	1.5	4.5	1.2	3.7
1 Gigabit Ethernet port	0.3	1.7	0.3	1.3
Wi-Fi interface single IEEE 802.11b/g or 11a radio	1.0	2.0	0.7	2.0
Wi-Fi interface single IEEE 802.11n Draft 2 radio	1.0	2.5	1.0	2.5
Wi-Fi interface dual (2.4 GHz and 5 GHz) IEEE 802.11n Draft 2 radio	2.0	5.0	2.0	5.0
Alternative LAN technologies (HPNA, MoCA®, POF, etc.)	4.0	4.0	2.0	2.5
Powerline	4.0	4.0	2.5	3.0
FXS	0.8	1.5	0.5	1.5
FXO	0.4	0.9	0.4	0.9
DECT GAP	1.0	1.65	0.75	1.65
DECT Cat-iq	1.0	2.0	0.75	2.0
DECT charging station for handset in slow/ trickle charge	0.5	0.0	0.4	0.0
USB	0.3	0.3	0.25	0.25
Bluetooth	0.2	0.3	0.2	0.3
Femto cell	9.0	9.0	7.0	8.0
Embedded handsfree system	0.5	0.5	0.5	0.5
Additional Color Display TFT QVGA and VGA	0.7	2.0	0.5	1.0

a. http://re.jrc.ec.europa.eu/energyefficiency/pdf/CoC%20Brodband%20Equipment/Code%20of%20Conduct%20Broadband%20Equipment%20V3%20final.pdf

Off and Standby State Allowances

In Off and Standby state, the total power consumed by the device, including power supply inefficiencies, must comply with what is given in Table 3.

Table 3: EuP Off and Standby State Allowances[a]

	1 Year After Regulation Comes into Force		4 Years After Regulation Comes into Force	
	Off State (W)	Standby State (W)	Off State (W)	Standby State (W)
Allowed power consumption	1	1	0.5	0.5

a. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:EN:PDF

Broadcom Reference Designs

This white paper discusses five reference designs available from Broadcom that are compliant with the CoC 2011 targets. These reference designs support a voice module, therefore, the configurations tested for low-power mode are presented with and without the voice module.

- BCM96358RAVN2G is a low-power ADSL2+ solution. It uses the BCM53101 as an external Ethernet switch.
- BCM96368MVNgr is a low-power VDSL and ADSL2+ solution.
- BCM96362ADVNgr is a low-power, high-performance ADSL2+ solution.
- BCM96328AVNG is a low-power, cost-effective ADSL2+ solution.
- BCM96328AVNgr is a lower-power, cost-effective ADSL2+ solution. BCM96328AVNG is a precursor to the BCM96328AVNgr.

Power-Saving Features

A number of power-saving features have been implemented on the Broadcom reference designs. These features address power consumption from a number of components. The list provided here is not comprehensive since Broadcom continues to develop new power-saving features.

Power Regulators

Switching regulators are used on the reference designs because they are much more efficient than linear regulators. The reference designs use either the TPS65230 or the TPS65250.

MIPS

When it is not executing any code, the Host MIPS core can be placed in a low-power mode by invoking the WAIT instruction. This instruction turns off a number of internal clocks and allows significant power-savings. The WAIT instruction is invoked anytime the processor has no work to do. Any interrupt (timer, packet, etc.) instantaneously resumes normal processing.

Ethernet

Broadcom uses the most recent technology for its Ethernet Switches, whether they are integrated or external. These new-generation 65 nm switches use less power to provide the same functionality as their precursors.

The integrated or external Ethernet PHYs on Broadcom chips also support an Auto Power-Down mode that turns off the power to the Ethernet PHY when either no cable is connected or the Ethernet port at the other end is down. The PHY remains capable of detecting energy on the port and resuming normal activity when an active device is connected to the port.

When all cables are disconnected from the switch, it is placed in a sleep mode, further saving power while still remaining capable of detecting energy on any port and resuming normal activity in a timely manner.

Wireless

For WLAN solutions that implement 2x2 reception and transmission, if little activity is detected on the Wireless connections, the integrated or external Wireless chips can be configured to reduce the number of RF chains for reception and transmission from 2x2 to 1x1.

USB Host

If the USB Host interface is not an available option on the CPE, the associated analog and digital components are shut down to save power.

PCIe™

The PCIe™ interface is available on the BCM6362 and BCM6328 chips, but it is not always in use. If no PCIe device is enumerated at boot time, the PCIe interface will be shut down. If the PCIe interface is used for external Wireless LAN support, it is placed in a low-power mode that greatly reduces its power consumption.

Broadcom Standby State

The Lot 6 regulation requires Broadband equipment to support either an Off switch or a Standby button. For products supporting the Standby button, this regulation only provides recommendations on how the Standby state should behave. Broadcom has implemented this Standby state using the combination of a CPLD and software.

The user first enables the standby feature on a web interface. Users program a time of day when they do not plan to use the modem and during which it should go to standby mode. Users also program a time of day when the unit needs to return to normal operations.

When the standby time is reached, software automatically programs a standby timer in the CPLD with a duration (the time when to wake up minus the time when to go to standby) and programs the CPLD to enter the Standby state. The CPLD shuts down power to all components on the board with the exception of the CPLD itself. While in Standby state, the power LED on the modem performs a “breathing” pattern, periodically decreasing intensity then increasing it again. When the standby timer on the CPLD expires, the CPLD resets the board, which resumes normal operations.

The user can press a Standby/Wake-up button at any time to force the modem into the Standby mode or to take it out of Standby mode. If the modem is power-cycled while in standby, it resumes normal activity as if the Wake-up button had been pressed. If the modem is taken out of standby mode like this while in the middle of the current standby period (between the standby time and the wake-up time), it will only return to Standby state again when the next standby period is reached.

CoC Compliance of Broadcom Reference Designs

In this section, the power consumption allowed by the CoC for the currently available Broadcom DSL reference designs is determined, and these allowances are compared against the measured power consumption of each device.

Allowances for Low-Power and On States

Examples of the power allowances for the BCM96358RAVN2G reference design are presented in Table 4. These allowance are calculated based on the features supported by the reference design. Broadcom only considers the Tier 2011 CoC targets, which are more restrictive than the Tier 2009/2010 targets.

Table 4: CoC Allowances for BCM96358RAVN2G DSL Reference Designs

	Tier 2009/2010		Tier 2011	
ADSL/ADSL2/ADSL2+	**Low-Power State (W)**	**On State (W)**	**Low-Power State (W)**	**On State (W)**
Fast Ethernet switch, up to 4 ports	0.8	2.2	0.6	1.8
Wi-Fi interface single IEEE 802.11n	1.0	2.5	1.0	2.5
USB	0.3	0.3	0.25	0.25
Total (CoC Target)	**6.30**	**10.00**	**4.45**	**8.35**

Measured Power Consumption vs. Allowances for Low-Power and On States

The reference designs were tested under the different CoC states, and their consumed power was measured. The results for the Low-Oower and On states are given in Table 5 and Table 6.

Note: When the IEEE 802.11n BCM4313 WLAN chip is used by the reference design, the COC 2011 target was computed using the allowance for IEEE 802.11g because the BCM4313 only supports a 1x1 radio. The CoC does not make such distinction, but Broadcom preferred to use the lower of the two values for computing the target power.

Table 5: Power Consumptions vs. Allowances for Low-Power State

			Measured Power		
Ref. Design	**Description**	**2011 Target (Watts)**	**Watt @ AC**	**Diff.**	**% Below**
96362ADVNgr	ADSL2+, 4FE, 802.11n, USB	4.45	3.200	–1.250	–28%
	ADSL2+, 4FE, 802.11n, USB, 2 FXS	5.45	3.300	–2.150	–39%

Table 5: Power Consumptions vs. Allowances for Low-Power State (Cont.)

Ref. Design	Description	2011 Target (Watts)	Measured Power		
			Watt @ AC	Diff.	% Below
96328AVNgr	ADSL2+, 4FE, 802.11n (4313), USB, GE	4.45	3.650	–0.800	–18%
	ADSL2+, 4FE, 802.11n (4313), USB	4.15	3.450	–0.700	–17%
	ADSL2+, 4FE, 802.11n (4313)	3.9	3.400	–0.500	–13%
96328AVNG	ADSL2+, 4FE, 802.11n (4313), USB, GE	4.45	4.000	–0.450	–10%
	ADSL2+, 4FE, 802.11n (4313), USB	4.15	3.800	–0.350	–8%
	ADSL2+, 4FE, 802.11n (4313)	3.9	3.750	–0.150	–4%
	ADSL2+, 4FE, 802.11n (43224), USB	4.45	3.950	–0.500	–11%
96368MVNGR	VDSL2, 4FE, 802.11n (43222), USB	5.35	5.200	–0.150	–3%
	VDSL2, 4FE, 802.11n (43222), USB, 2 FXS	6.35	5.400	–0.950	–15%
96358RAVN2G	ADSL2+, 4FE, 802.11n, USB	4.45	4.300	–0.150	–3%

Table 6: Power Consumptions vs. Allowances for On State

On Mode		2011 Target	Measured Power		
Ref. Design	Description	Watts	Watt@AC	Diff.	% Below
96362ADVNgr	ADSL2+, 4FE, 802.11n, USB	8.35	4.400	–3.950	–47%
	ADSL2+, 4FE, 802.11n, USB, 2 FXS	11.35	5.400	–5.950	–52%
96328AVNgr	ADSL2+, 4FE, 802.11n (4313), USB, GE	8.35	6.600	–1.750	–21%
	ADSL2+, 4FE, 802.11n (4313), USB	7.85	5.900	–1.950	–25%
	ADSL2+, 4FE, 802.11n (4313)	7.6	5.850	–1.750	–23%
96328AVNG	ADSL2+, 4FE, 802.11n (4313), USB, GE	9.15	6.700	–2.450	–27%
	ADSL2+, 4FE, 802.11n (4313), USB	7.85	6.000	–1.850	–24%
	ADSL2+, 4FE, 802.11n (4313)	7.6	5.950	–1.650	–22%
	ADSL2+, 4FE, 802.11n (43224), USB	8.35	6.100	–2.250	–27%
96368MVNGR	VDSL2, 4FE, 802.11n (43222), USB	10.55	7.300	–3.250	–31%
	VDSL2, 4FE, 802.11n (43222), USB, 2 FXS	13.55	8.100	–5.450	–40%
96358RAVN2G	ADSL2+, 4FE, 802.11n, USB	8.35	6.000	–2.350	–28%

Measured Power Consumption vs. Allowances for Off and Standby States

All BCM963xxGR and the BCM96358RAVN2G reference designs optionally support the CPLD required to implement the Standby state. Measurements were only taken on the BCM96358RAVN2G, with the results given in Table 7, but the same results are applicable to all these reference designs and are also achievable on other reference designs that support the CPLD. If no CPLD is supported, only the results for the Off state are applicable.

Note: The results depend greatly on the AC/DC power supply used for testing.

Table 7: Power Consumption vs. Allowances for Off and Standby States

	1 Year after Regulation Comes into Force		4 Years after Regulation Comes into Force	
BCM96358RAVN2G	**Off State (W)**	**Standby State (W)**	**Off State (W)**	**Standby State (W)**
EuP Lot 6 Target	1	1	0.5	0.5
Measured Contribution from Ref design	0	0.215	0	0.215
Measured Contribution from Power supply[a]	0.1	0.285	0.1	0.285
Measured Total[b]	0.1	0.5	0.1	0.5
Difference (Below Target)	0.9	0.5	0.4	0

a. Using GS40A12-P1J or PSM11R-120 reports 0.0 Watt; sometimes 0.1 or 0.2 Watt is reported on a "Watts up?" device.
b. All measured totals performed using a "Watts up?" device at 110V.

Availability

The power-saving features for the Broadcom Reference designs are available beginning with the following releases.

Table 8: Broadcom Releases with Power Saving Features

	Broadcom Device	
Release	**BCM6358**	**BCM6362, BCM6328, BCM6368**
Production Release	4.04L.02	4.06L.01

Enabling and Disabling CoC Features in Broadcom Production Software Releases

Some features are enabled by default and can be disabled; others are disabled by default and can be enabled.

MIPS Wait Instruction

The MIPS Wait instruction is always enabled by default. It can be disabled for testing purposes by enabling Power Management in the `make menuconfig` commands, as follows:

```
make menuconfig
```

Select other features:

```
<M> PWRMNGT Driver

<dynamic> PWRCTL
```

Then you can go on the WebUI page, under Power Management, and disable this feature. Note that changes made in WebUI are saved over reboot. Alternately, the following command can be issued from the shell prompt on the modem:

```
pwrctl config –cpur4kwait off
```

Ethernet

In release 4.06L.01, the Ethernet power-saving features are enabled when the PWRMGNT Driver module is added to the compile options through `make menuconfig`, as described above. In 4.06L.02 and subsequent releases, the Ethernet power-saving features are enabled independently from the PWRMGNT Driver by setting the following option in make menuconfig:

```
[*] Ethernet Auto Power Down and Sleep
```

Wireless

To enable the Wireless power-saving feature, edit the file cms-data-model.xml using the Data Model Designer or by manually editing the file and change the default of this entry to 1 (enable):

```
WlRxChainPwrSaveEnable
```

USB Host

The USB Host power-saving features take effect when USB is disabled at compile time through the `make menuconfig` options.

PCIe

For designs that don't use the PCIe bus, the software that turns off the PCIe bus when no device enumerates is always enabled. For designs using the PCIe bus, the PCIe power-saving feature is enabled by setting the following option in `make menuconfig`:

```
[*] PCIe L1 Active State Power Management
```

CPLD Standby Timer

The CPLD Standby timer is optional and can be compiled in by enabling the CPLD Standby Timer feature through the `make menuconfig` command.

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