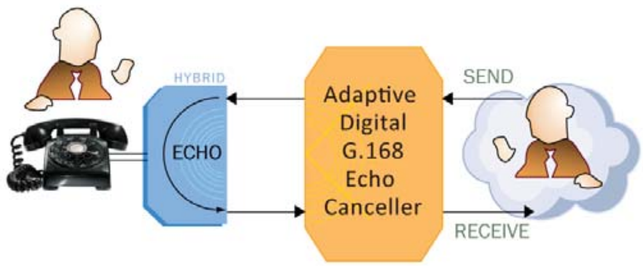
G.168 Echo Canceller- *Line, Network and Packet*

G.168 and G.168 Plus™ Packet EC

HIGHLIGHTED FEATURES

- Cancels echo caused by 4 to 2 wire conversion circuits that exist in FXS and FXO and in SLIC and DAA circuits
- Ideal for use in VoIP gateway, IP PBX, ATA, and digital network echo cancellers
- Available on TI TMS320C54X, TMS320C55X, TMS320C6000 DSPs as well as ARM9E, ARM Cortex-A8/A9/A15, and ARM Cortex-M3/M4, PC/Windows, and Linux/x86
- Supports tail lengths as long as 512 milliseconds
- Cancels multiple reflectors
- G.164/G.165/V.8 tone disabler
- SS7 Tone Detection
- Stationary signal detector prevents divergence due to tones and other periodic signals
- Tandem free operation
- Robust double-talk detection
- Natural sounding comfort noise generator
- Configurable parameters
- Meets and exceeds ITU G.168 requirements



PRODUCT DESCRIPTION

With a strong focus on providing optimum voice quality, Adaptive Digital's G.168 echo canceller cancels echo that is caused by 4 to 2 wire conversion (hybrid) circuits that exist in telephone equipment. Our echo canceller, first developed and deployed over 15 years ago, carries with it the robustness that comes from the combination of careful design, relentless testing, and widespread deployment.

Adaptive Digital's echo canceller qualified as toll-quality at AT&T's Voice Quality Assessment Labs in Middleton, NJ. AT&T's Voice Quality Assessment Lab evaluated Adaptive Digital's echo canceller using its stringent series of performance tests including AT&T's Mean Opinion Score (MOS) subjective tests as well as the standardized set of G.168 objective tests. The subjective and objective performance of Adaptive Digital's echo canceller surpassed even the performance of AT&T's benchmark lab echo cancellers.

The importance of subjective testing should not be overlooked. Although the ITU's G.168 recommendation is well thought out, this type of objective test is no guarantee that an echo canceller will sound good to a human listener. By doing both subjective (MOS) and objective (G.168) testing, Adaptive Digital ensures the optimum voice quality, which is, after all, what it's all about!

Another important reason for solid subjective performance testing is that G.168 is not a bit-exact specification. When an algorithm is specified in a bit-exact way, every compliant implementation will sound identical. This is the case for most of the standardized vocoders. In contrast, G.168 specifies test conditions, excitations, and required *minimum* output performance. As a result, the voice quality achieved by different echo cancellers varies greatly. Beyond all the lab testing that can and should be done, there is no substitute for lessons learned through years of real-world deployment.

The G.168 Plus™ packet echo canceller has the unparalleled ability to handle round-trip delays of up to 512 milliseconds. This ability to cancel echoes with exceptionally long delays, coupled with a built-in awareness and handling of packet-loss makes G.168 Plus uniquely suitable for VoIP applications. Echo, latency and packet loss are the major causes of poor quality in VoIP applications. Adaptive Digital's innovative G.168 Plus packet greatly reduces the impact of these impairments that have plagued voice quality over IP networks since its inception.

The overall importance of echo cancellation should also not be overlooked. From the users' perspective, echo is arguably the worst type of impairment that can be encountered during a telephone conversation.

ECHO CANCELLER VARIANTS

Adaptive Digital's G.168 echo canceller comes in three variants, each of which is designed to suit a specific type of application. The three variants are Line EC, Network EC, and Packet EC.

Line Echo Canceller

The Line EC (LEC) is designed to operate inside a device that has a local hybrid circuit. The hybrid circuit is the circuit that converts between a4-wire and a 2-wire interface. Hybrid circuits include:

- SLIC (Subscriber Line Interface Circuit)
- FXO (Foreign Exchange – Office)
- FXS (Foreign Exchange – Subscriber)
- DAA (Data Access Arrangment)

Examples of equipment that need a line echo canceller include:

- ATA
- VoIP Gateway with FXO and/or FXS interfaces

The significance of the local hybrid is that there is little delay between the hybrid, the source of the echo, and the echo canceller.

Network Echo Canceller

The Network Echo Canceller (NEC) is designed to operate in a piece of network equipment that may not have an internal echo source. The echo source may be elsewhere in the network. Examples of equipment that may need an echo canceller include:

- VoIP Gateway with digital trunks
- T1/E1 echo canceller

Since the echo source is elsewhere in the network, the network echo canceller must be able to deal with longer echo delays than the line echo canceller. It must also be able to handle signaling tones that are found in the telephone network. It may also need to cancel reflections caused by more than one hybrid circuit in the network. Finally, the network echo must be able to deal with echo-free circuits or circuits in which the echo is already cancelled at the source.

Packet Echo Canceller

The conventional wisdom tells us that an echo canceller should be as “close to” the echo source (hybrid) as possible. For a variety of reasons, this makes the echo canceller perform better. But the introduction of the Voice –Over-IP network, the conventional wisdom has been turned on its side. The added delay incurred by the packet network can cause echo that is not otherwise perceptible to become a problem. This may include not only echo due to hybrid circuits but also some residual acoustic echo from handsets or hands-free devices. As a result, there could be equipment in the field that did not require echo cancellation before VoIP entered the picture.

Since it is not feasible to modify all such equipment, it is sometimes necessary for an echo canceller in a packet network to cancel echo whose source is on the opposite end of the packet network. A packet network echo canceller must be able to handle excessively long echo delays. It must also be able to operate well whether there is echo or not. In fact, it is far more common that a connection be echo free because the echo is cancelled at the source. Furthermore, a packet echo canceller must be able to deal with the presence of speech compression algorithms within the VoIP network.

Examples of equipment that may need a packet echo canceller include:

- VoIP Gateway
- VoIP Conference Server

ECHO OVERVIEW

Echo in the telephone network is caused by hybrid circuits that convert between two-wire and four-wire analog interfaces, as seen in figure 1

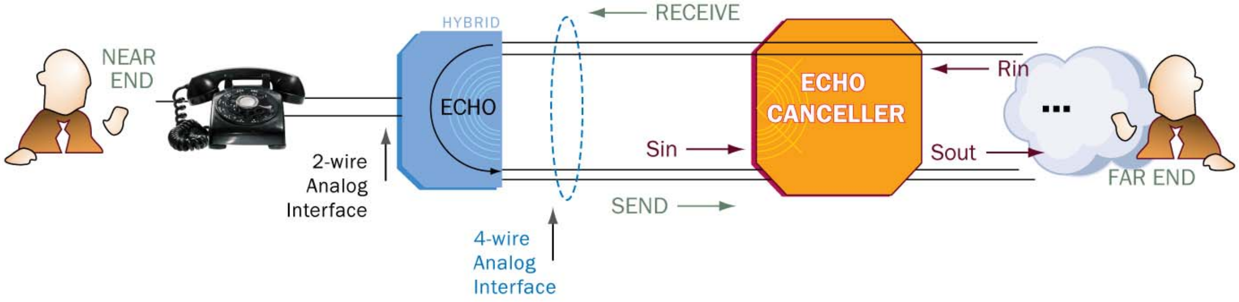


Figure 1

At the four-wire side of the hybrid, one pair of wires carries voice signals toward the hybrid (sometime called the receive path), and a second pair of wires carries voice signals away from the hybrid (sometimes called the send path). On the two-wire side of the hybrid, a single pair of wires carries voice signals in both directions. The echo comes about because hybrid circuits are not perfectly matched. As a result, some of the four-wire receive signal is leaked back into the four-wire send signal.

We will refer to the person speaking at the four-wire side as the far end speaker, and the person speaking at the two-wire side as the near end speaker.

ECHO TAIL

If we characterize a hybrid in terms of its impulse response, we see that the impulse response tends to be non-zero for a few milliseconds, but can be as long as 16 milliseconds. The impulse response is often referred to as the echo tail, and the duration of the echo tail is often referred to as the tail length. The tail length of the echo tail shown in figure 2 is 8 milliseconds.

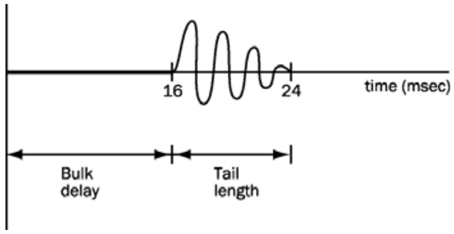


Figure 2

There are situations where the echo canceller is not located at the same location as the hybrid. It may be separated by one or more T-1 links or other types of links that cause the tail length appear to be even longer from the point of view of the echo canceller. Furthermore, there may be more than one hybrid in the path – resulting in an overall impulse response that is the concatenation of multiple impulse responses. In this case, each tail is sometimes referred to as a reflector, and the situation where there are multiple hybrids in a circuit is referred to as one where there are multiple reflectors.

BULK DELAY

There are situations where an echo canceller may be on the opposite side of a VoIP or satellite link from the hybrid. In this case, the there is considerable delay between the echo canceller and the hybrid in both directions. In this case, the echo tail appears to begin with a segment of zeros followed by the hybrid impulse response as shown in figure 2. The duration of the segment of zeros is referred to as the bulk delay.

There are two ways to handle bulk delay. One is to place an artificial delay into the far end input to the echo canceller to effectively remove the bulk delay from the point of view of the echo canceller. This technique falls short for two reasons. First of all, it requires a-priori knowledge about the amount of bulk delay that will be encountered. Second, it does not allow for the situation where there may be a local reflector and a remote reflector. Because of both of these reasons, it may be preferred to use a second technique in which the entire possible delay window is analyzed, and any reflectors within that window are cancelled.

PACKET LOSS

Packet loss (the situation in which some voice packets fail to reach their destination) can be extremely detrimental to echo cancellers that are unaware of the packet loss and are ill equipped to deal with it. If the echo canceller is unaware of the momentary data interruption, it will process the synthesized data that fills in for the lost signal as if the echo were present. This can prevent the echo canceller from being able to detect and cancel the echo. Even worse, the lost data can cause the echo canceller to incorrectly determine the characteristics of the echo and, in its attempt to remove echo that isn't truly an echo, render the speech unintelligible during the period of packet loss and beyond. Adaptive Digital's G.168 Plus product provides a truly unique solution to what would otherwise be a lost call.

ECHO CANCELLATION

The primary job of an echo canceller is to remove the echo of the receive path that has bled through the hybrid into the send path. This is done by modeling the echo path with an adaptive filter, using that adaptive filter to predict the echo, and subtracting the predicted echo from the send signal. This is shown in figure 3.

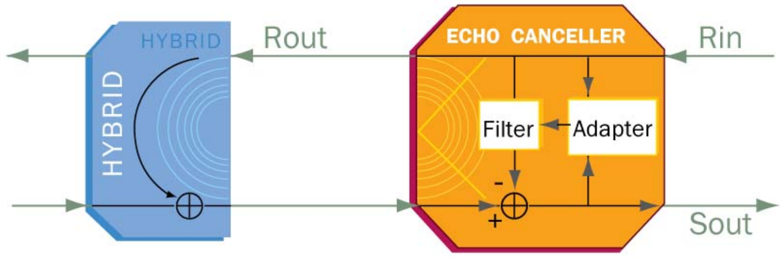


Figure 3

But, as we will explain, there is far more to an echo canceller than meets the eye for a number of reasons.

The ideal situation for an echo canceller to model the echo tail is when the far end speaker is speaking and the near end speaker is silent. This condition is referred to as single-talk. The reason this is ideal is that the receive signal is used as a reference signal for the echo canceller for comparison with the send signal. If both the far end speaker and the near end speaker are speaking at the same time (a condition known as double-talk condition), the near end speech will be added to the echo thereby making it more difficult for the echo canceller to compare it to the reference. In fact, a double-talk condition can cause an echo canceller's adaptive filter to diverge. In order to prevent this from happening, echo cancellers employ double-talk detectors**.** When double-talk is detected, the echo canceller temporarily stops adapting its filter to prevent divergence.

NONLINEAR PROCESSING

Echo cancellers use adaptive filters that do not perfectly model the echo tail. As a result, the echo cancellers have to perform post-processing (Nonlinear Processing or NLP) to remove the residual echo caused by the imperfections. Similarly, the echo path may have some nonlinearities that the adaptive filter cannot perfectly match. The NLP is intended to take care of this also.

The NLP has to be designed carefully in order to minimize unwanted effects. The nonlinear processor is free to suppress residual echo at will in a single-talk situation. But if it is too aggressive during a double-talk situation it may suppress the near end speech – an undesirable effect.

Another more subtle effect of an NLP occurs when there is background noise at the near end. This background noise will be heard by the far end speaker when the NLP is not engaged, but the noise will be suppressed when the NLP is engaged. The appearance and disappearance of the background noise can be annoying. In order to take care of this, an echo canceller will often replace the residual signal with comfort noise while the NLP is engaged rather than blindly suppressing the signal. When an echo canceller has this feature, it is referred to as a comfort noise generator (CNG).

An overly aggressive NLP may also cause DTMF digits to be partially clipped (in duration). The possible consequence is that a DTMF detector may not detect a tone that should have otherwise been detected. In situations where an application needs an aggressive NLP, this problem can be circumvented by outputting both the pre-NLP and post-NLP signals. The DTMF detector can be fed the pre-NLP signal.
Beyond nonlinearities in the echo path, there can be other impairments that an echo canceller may need to deal with.

- Residual Acoustic Echo: There may be some residual echo on the line if the near end speaker is using a hands-free phone that does not have a good acoustic echo canceller. In this case, the network echo canceller has an opportunity to attack this source of echo. There can also be some residual echo when using a non-hands-free phone. This echo is caused by acoustic coupling between the handset earpiece and microphone. The level of this echo is usually small.
- Packet Loss: If an echo canceller is placed on the opposite side of a packet network with respect to the hybrid, a lost packet causes an interruption in the echo path. This can cause an echo canceller to diverge. in the echo path such as PCM slips, packet loss (in a packet network), and residual acoustic echo from a hands-free phone. Ideally, an echo canceller should do its best to mitigate the effects of these impairments as well.

TANDEM FREE OPERATION

Yet another scenario that an echo should deal with is the one where there is another echo canceller in a circuit that is closer to the hybrid than ours. In this case, the other echo canceller should remove the echo leaving our echo canceller the appearance that there is no hybrid in the circuit. Under these circumstances, an echo canceller could actually create echo rather than leave the echo-free signal alone. Being able to handle this situation properly is referred to as tandem free operation. A similar situation is one in which an echo canceller is placed on a circuit that does not have a hybrid.

ADDITIONAL ECHO CANCELLER REQUIREMENT

The telephone system carries more than just voice signals. It can carry fax and modem signals, signaling tones (such as DTMF tones and inter-office signaling tones). Passing these tones properly imposes additional constraints on an echo canceller. For example, an echo canceller must detect the presence of certain modems by identifying their answer tones (as specified by ITU G.165, V.8). When these modems are present, the echo canceller must disable itself for the duration of the modem connection. Similarly, when certain interoffice signaling tones known as SS7 tones are present, the echo canceller must disable itself temporarily. This feature is known as a tone disabler.

The moral of the story is – use a top-notch echo canceller. A reputation for good voice quality is difficult to achieve. A reputation for bad voice quality is easy to achieve and difficult to overcome.

FEATURE COMPARISON

Adaptive Digital's echo canceller is offered in three variants, which are compared by feature set in the following table.

Feature	G.168 LEC	G.168 NEC	G.168 Plus™ Packet EC
Maximum Tail Length	**16 msec**	**128 msec**	**512 msec ***
Tandem Free Operation *	X	X	X
High Efficiency Tandem Free Operation *			X
Packet Loss Concealment *			X
Dynamic* NLP	X	X	X
Natural Comfort Noise Generator	X	X	X
Rapid Convergence	X	X	X
Automatic Tail Search		X	X
Cancels multiple reflectors	X	X	X
Convergence Monitor *	X	X	X
Tone Disabler	X	X	X
SS7 Tone Detection		X	X
Double-talk Detection	X	X	X
Stationary Signal Detector	X	X	X
Pre-NLP Signal Available*	X	X	X
Split Pre- and Post- Processing *	X	X	X
Handles Residual Acoustic Echo	X	X	X
Functions are "C" callable	X	X	X
User Configurable Parameters	X	X	X

** indicates that this feature is an enhancement beyond the G.168 recommendation*

AVAILABLILITY

ADT G.168 Line, Network, and Packet echo canceller is available on the following Platforms: Other configurations are available upon request.

LINE ECHO CANCELLER – Short Tail 8 – 32 msec.

Product	Platform	Memory Model	Endian	Code Gen Tool Version
ADT_168lec_c64xp	TI TMS320C64x+	L3	Little	N/R
ADT_168lec_c64x	TI TMS320C64x	L3	Little	6.1.15
ADT_168lec_c62x	TI TMS320C62x	L3	Little	N/R
ADT_168lec_c55x	TI TMS320C55x	L3	Little	N/R
ADT_168lec_c54x	TI TMS320C54x	Far	N/A	N/R
ADT_168lec_arm11	ARM11	N/A	Little	N/R
ADT_168lec_arm9	ARM9	N/A	Little	N/R

NETWORK ECHO CANCELLER – Long Tail 32 – 128 msec.

Product	Platform	Memory Model	Endian	Code Gen Tool Version
ADT_168nec_c64xp	TI TMS320C64x+	L3	Little	N/R
ADT_168nec_c64x	TI TMS320C64x	L3	Little	6.1.15
ADT_168nec_c55x	TI TMS320C55x	L3	Little	N/R
ADT_168nec_c54x	TI TMS320C54x	Far	N/A	N/R
ADT_168nec_x86	Linux x86	N/A	Little	N/R
ADT_168nec_armA8/A9/A15	ARM Cortex-A8/A9/A15	N/A	Little	GCC v 4.6.1
ADT_168nec_armM3/M4	ARM Cortex-M3/M4	N/A	Little	GCC v 4.6.1
ADT_168nec_arm11	ARM11	N/A	Little	GCC v 4.6.1
ADT_168nec_arm9	ARM9	N/A	Little	GCC v 4.6.1

PACKET ECHO CANCELLER – extra-Long Tail 128 – 512 msec.

Product	Platform	Memory Model	Endian	Code Gen Tool Version
ADT_168nec_c64xp	TI TMS320C64x+	L3	Little	N/R
ADT_168nec_c64x	TI TMS320C64x	L3	Little	N/R
ADT_168nec_c55x	TI TMS320C55x	L3	Little	N/R
ADT_168nec_x86	Linux x86	N/A	Little	N/R

SPECIFICATIONS

TI TMS320C6000

C64x+

CPU UTILIZATION & MEMORY REQUIREMENTS

All Memory usage is given in units of byte.

Tail Length	MIPS (Peak)	Program Memory	Data Memory	Scratch Mem Single Access	Per-Channel Data Memory
16 msec.	4.3	23296	1034	--	1466
32 msec.	4.5*	43200	996	984	2238
64 msec.	5.7*	43200	996	1180	3458
128 msec.	7.2*	43200	996	1472	5506
*256 msec.	5.1	29280	6502	--	8804
*384 msec.	5.7	29280	8934	--	12260
*512 msec.	6.1	29280	11366	--	15716

Last update: 8/2011

*NOTE: Tail lengths of **256**, **384**, & **512** msec. are only supported in the **G.168Plus™ Packet EC**.
*NOTE: Worst case, consult User's Guide for reduced complexity specs.

C64x

CPU UTILIZATION & MEMORY REQUIREMENTS

All Memory usage is given in units of byte.

Tail Length	MIPS (Peak)	Program Memory	Data Memory	Per-Channel Data Memory	Scratch Memory
16 msec.	5.73	37152	3179	1709	1157
32 msec.	4.13	45888	3297	2250	1417
64 msec.	4.91	45888	3297	3370	2125
128 msec.	6.07	45888	3297	5418	3441
*256 msec.	5.2	31264	6502	8804	-
*384 msec.	5.8	31264	8934	12260	-
*512 msec.	6.2	31264	11366	15716	-

Last update: 7/2012

*NOTE: Tail lengths of **256**, **384**, & **512** msec. are only supported in the **G.168Plus™ Packet EC**.

C62x

CPU UTILIZATION & MEMORY REQUIREMENTS

All Memory usage is given in units of byte.

	MIPS (Peak)	Program Memory	Data Memory	Per-Channel Data Memory
16 msec. tail	3.4	17321	852	1332
32 msec. tail	4.2	17321	1108	2114

Last update: 10/26/2005

TI TMS320C5000

C55x

CPU UTILIZATION & MEMORY REQUIREMENTS

All Memory usage is given in units of byte.

	MIPS (Peak)	Program Memory	Data Memory	Per-Channel Data Memory
8 msec. tail	3.8	9833	1406	968
16 msec. tail	4.7	9833	1662	1376
32 msec. tail	6.3	9833	2174	2192
64 msec. tail	6.6	12663	3594	3266
128 msec. tail	7.4	12663	5642	5122
*256 msec. tail	8.2	13686	9738	8834
*384 msec. tail	10.4	13686	13834	12546
*512 msec. tail	12.4	13686	17930	16258

Last update: 06/16/2010

*NOTE: Tail lengths of **256**, **384**, & **512** msec. are only supported in the **G.168Plus™ Packet EC**.

C54x

CPU UTILIZATION & MEMORY REQUIREMENTS

All Memory usage is given in units of 16-bit word.

	MIPS (Peak)	Program Memory	Data Memory	Per-Channel Data Memory
8 msec. tail	3.8	6462	1364	484
16 msec. tail	4.7	6462	1364	688
32 msec. tail	7.1	7666	1066	1048
64 msec. tail	8.1	7666	1370	1511
128 msec. tail	9.5	7666	1978	2440

Last update: 04/03/2012

ARM® DEVICES

ARM Cortex-A8/A9/A15

CPU UTILIZATION & MEMORY REQUIREMENTS

All memory requirements are in units of byte.

Product	Tail Length	MIPS	Program Memory	Data Memory	Per-Channel Data Memory	Scratch
G.168	16 msec	50.1	46768	3036	1709	1157
	32 msec	28.8	61152	3136	2250	1417
	64 msec	46.6	61152	3136	3370	2125
	128 msec	77.6	61152	3136	5418	3441

ARM Cortex-M3/M4

CPU UTILIZATION & MEMORY REQUIREMENTS

All memory requirements are in units of byte.

Product	Tail Length	MIPS	Program Memory	Data Memory	Per-Channel Data Memory	Scratch
G.168	69.5	34268	3036	1709	1157	69.5

ARM9/11

CPU UTILIZATION & MEMORY REQUIREMENTS

All memory requirements are in units of byte.

Product	Tail Length	MIPS	Program Memory	Data Memory	Per-Channel Data Memory	Scratch
G.168	16 msec	46.0	46688	3036	1709	1157
	32 msec	28.5	61736	3136	2250	1417
	64 msec	45.4	61736	3136	3370	2125
	128 msec	75.5	61736	3136	5418	3441

Linux x86

CPU UTILIZATION

Variant	Platform	Average MIPS*	Peak MIPS
LEC	32 bit		72
LEC	64 bit		28
NEC	32 bit		124
NEC	64 bit		48
PEC	32 bit	19	148
PEC	64 bit	8	60

* PEC average MIPS characterized with smart packet optimization set to maximum on echo-free circuit

PC-WINDOWS

PLATFORM PC-WINDOWS

Contact Sales 610-825-0182

FUNCTION	
`LEC_ADT_g168Init(…)`	`Initializes echo canceller channel`
`LEC_ADT_g168Cancel(…)`	`Executes cancellation function`
`LEC_ADT_g168echoCancel(..)`	`Executes pre-NLP function (split API)`
`LEC_ADT_g168postCancel(..)`	`Executes NLP function(split API)`
`LEC_ADT_g168RuntimeConfig`	`Changes modifiable EC parameters`
`LEC_ADT_g168GetConfig(…)`	`Gets parameters and status of the EC`

Deliverables

The deliverable items are platform dependent. In general, there is one library. (Sometimes multiple variants of the library are included in the deliverables.) There are also header files, some of which are specific to the product and others are common across many of Adaptive Digital's products. Also included in the deliverables is product documentation, which includes a users guide and usually includes release notes and a data sheet. Sample/test code may be included as well.

Adaptive Digital is a member of the Texas Instruments Developer Network, and ARM Connected Community.

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