



# Philips Avalon Fetal Monitoring

## Avalon Smart Transducers

### Application Note

For Avalon Fetal Monitors Rev. J.3x.xx onwards

The Philips Avalon family of fetal monitoring products provides cutting edge solutions for fetal/maternal monitoring, setting new standards in performance, reliability, flexibility, and ease of use. In developing its new generation of Fetal monitors, Philips has embraced a new design philosophy that has allowed new possibilities for the monitoring system. Here, Avalon Smart Transducers and the Avalon CL Transducer System play key roles.

## Traditional Design Approach and Limitations

Traditionally, fetal monitoring systems have been designed in such a way that the transducers provide the raw measurement data to the Fetal monitor, which then processes these signals via a dedicated channel in the Fetal monitor.

This approach has a number of limitations:

- As the analog-to-digital conversion, and subsequent processing of raw signals acquired by the transducer is carried out in the monitor, there is a relatively long analog signal path until the data is processed, which can have consequences such as an increased susceptibility to external interference.
- Different measurements are handled by different hardware components within the Fetal monitor. Each socket on the monitor accepts only the matching transducer for that measurement channel. This makes it restrictive in that the user must take care to ensure that the transducer for a particular measurement is connected to the correct, dedicated socket.
- Adding further measurements involves modifying the Fetal monitor hardware (for example, installing new measurement-specific boards). This also makes adding new measurements in the future difficult, and the total number of measurements is limited by what physically fits

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into the monitor.

## Flexible, Modular Design from Philips: The Smart Approach

Philips has taken a new approach when designing the Avalon Fetal Monitors and their Smart Transducers. Instead of letting the Fetal monitor perform the processing of measurement data, the Avalon Smart Transducers take care of this. Each transducer is equipped with its own 'brain', a central processing unit (CPU) and signal processing board. As the processing power for a measurement is within the transducer itself, adding a transducer does not place an additional performance burden on the monitor, but rather adds to the processing power of the whole system. So even when monitoring triplets, for instance, there is no compromise in performance, as each fetal heart rate measurement has its own, dedicated signal processing.

Signal acquisition, analog-to-digital conversion, and subsequent real-time signal processing are all done in the transducer, then the result is sent to the Fetal monitor for display and to be recorded. The Fetal monitor accepts signals from any Smart Transducer, which can be connected to any of the fetal sensor sockets.

The advantages of "being Smart" are clear:

### Very Short Analog Signal Path

The very short analog signal path within the Smart Transducer means that the signals are much less susceptible to electromagnetic interference.

### Digital Signal Transmission

Analog-to-digital conversion is done much closer to the source, in the Smart Transducer, so that only digital signals are transmitted to the Fetal monitor. Digital signal transmission offers a better signal-to-noise ratio, better reliability, and therefore enhanced performance.

### Modular Measurements

Each Smart Transducer can be regarded as a measurement module which can be attached to the monitor to provide patient data. You simply take a transducer for the measurement you want, and connect it to the monitor. To add parameters, for example, a second or third fetal heart rate, you just plug in the required additional transducers.

This also means that new measurements can be added easily by developing a new Smart Transducer, with no need to change the Fetal monitor hardware. Our latest example are the cabled Toco MP transducer and the CL Toco<sup>+</sup>MP transducer (part of the Avalon CL Transducer System).

## Integrated Measurements

Smart Transducer technology even allows several measurements to be integrated into one transducer, making monitoring more flexible, and reducing the number of transducers required. For example, the Toco<sup>+</sup> transducer has integrated measurement functionality for measuring intra-uterine pressure (IUP) and maternal and fetal ECG, in addition to external Toco measurements.

## Triplets Monitoring

Thanks to Smart Transducer technology, Philips can offer the ability to monitor and document up to three fetal heart rates externally using ultrasound cabled and cableless transducers (no mixed operation), the very first such solution using a single Fetal monitor. With Smart Transducer technology, it is possible to use the same ultrasound (US) transducer type for a second or third baby.

See the application note "Monitoring Triplets" for more details.

## Smart Means Convenient

Avalon Smart Transducers are designed to make life simpler and more convenient, with an easy use and maintenance concept for cost-effective long-term ownership.

## Standardized Connectors

All Avalon Smart Transducers have a standardized, D-shaped connector that allows easy connection to any of the corresponding fetal sensor sockets on the Fetal monitor, for simple "plug-and-play" convenience. The Avalon CL base station containing the CL transducers also connects to the fetal sensor sockets.



The Fetal monitor allocates a channel for the measurement automatically.

Fetal heart rate measurements are numbered in the order in which you plug in the transducers for those measurements. It does not matter which fetal sensor socket you use, as the monitor allocates a channel automatically. For instance, when monitoring triplets, the first transducer you connect is automatically allocated a channel, and the measurement is labeled FHR1, the second FHR2, and the third FHR3.

If you need to disconnect the transducers measuring the FHR temporarily, with the intention to continue monitoring after the temporary break (for example, if the mother needs to go to the bathroom), it is important that you reconnect the transducers in the same order as you originally connected them to make sure the measurement labels remain consistent.

The remote event marker and the Avalon CL Fetal Transducer System interface also share the same standardized connectors.

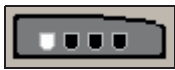
## Standardized Cable

All Smart Transducers also share the same type of cable, which is replaceable, ensuring the transducers have a very long effective working life. The new cable kit comes complete with a new sealing gasket, making sure your Smart Transducers remain watertight. This is another example of Philips' commitment to making your life simpler and reducing the overall cost of ownership.

## Two-Way Communication

Smart Transducers allow bi-directional communication with the Fetal monitor over a serial bus protocol. For example, this technology allows easy transducer identification using the **Finder LED**.

When you touch a measurement numeric on the screen, the setup menu for that measurement opens. The fetal sensor socket to which the transducer for this measurement is connected is identified by the transducer position indicator in the setup menu header:



for FM20/FM30



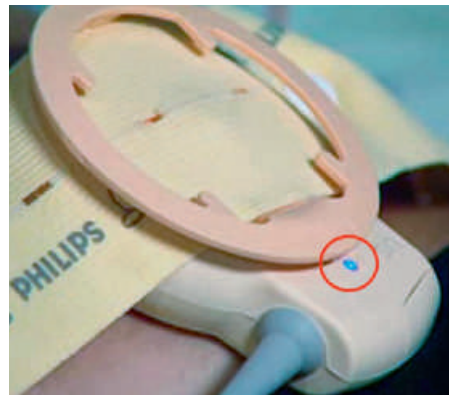
for FM40/FM50

When monitoring multiple fetal heart rates, the need may arise to reposition the ultrasound transducers relatively often compared to when monitoring a single fetus. To allow rapid transducer identification, and therefore correspondingly quick transducer repositioning, each transducer is equipped with a **Finder LED**.

Touching an FHR numeric on the screen...



...illuminates the bright, blue Finder LED on the corresponding transducer.



Transducer Finder LED

This allows you to identify at a glance which transducer is monitoring which heart rate channel, making repositioning the transducer quick, and easy.

Refer to the application note, "Monitoring Triplets", for further information about monitoring multiple fetal heart rates using Avalon Smart Transducers.

## Ergonomic Design

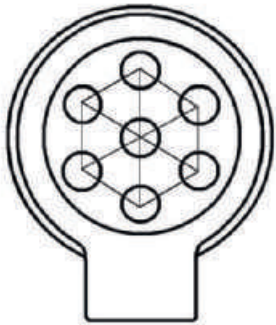
The Smart Transducers are ergonomically designed for maximum patient comfort.

# Advanced Technology

Avalon Smart Transducers employ advanced technology, which provides optimal performance.

## Optimal Ultrasound Crystal Placement

Smart Ultrasound transducers employ **seven ultrasound crystals** in an optimal geometric configuration. Six crystals are placed around the circumference and one in the center. The crystals are placed on the corners of equilateral triangles. This configuration allows the coverage area to be homogenous, or of equal signal strength throughout, providing an optimum solution in terms of cost, reliability, and performance.

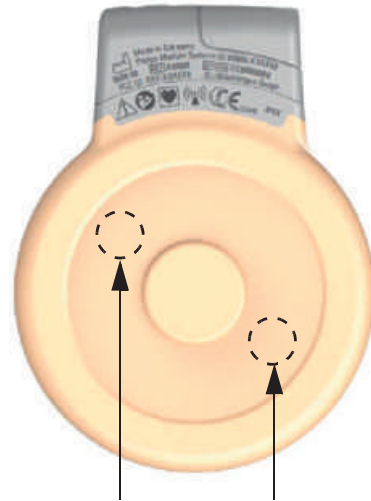


7 crystals: optimal placement, homogenous signal

The more homogenous the signal is, the greater is its accuracy and ability to provide a reliable signal, thus reducing the number of times the clinician needs to reposition the transducer. Using more than seven crystals (for example nine) within a transducer, means that there are no longer equidistant lines between the crystals, and the triangles created are isosceles triangles. This constellation is unlikely to provide a homogenous signal. Extensive research has shown that the Philips constellation of seven crystals provides an optimal solution.

## Avalon Smart Pulse

In addition to the Toco measurement, the Toco MP transducer (M2734B) and the CL Toco<sup>+</sup>MP transducer (866075) have two built-in sensors to measure the maternal pulse. The technology used is similar to SpO<sub>2</sub>, but measures the **maternal pulse (MP)** only.



Two maternal pulse sensors under the plastic surface

As described in different medical literature<sup>1</sup>, maternal or fetal heart rate coincidence is one major reason for incidents. Most of this literature recommends measuring the maternal heart frequency. Doing that the fetal heart rate can be compared with the maternal heart rate, in order to confirm that the fetal heart rate is not measured inadvertently from the pulsating maternal artery. Cross-channel verification (CCV), a standard feature for all Avalon Fetal monitors, processes automatically maternal pulse or heart rate derived from Smart Pulse SpO<sub>2</sub> or maternal ECG.

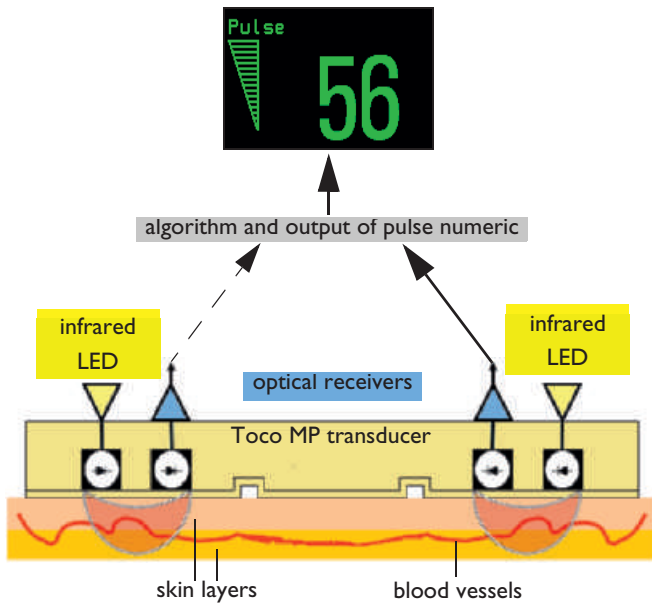
Additional parameters add effort for the clinicians and discomfort for the mother, and are not consistently utilized. Therefore the integration of Smart Pulse into the standard Toco transducer, enables monitoring the maternal pulse with ease and without giving up important information.

Philips Smart Pulse and CCV acts like an extra safety net. Both are always active when a Toco MP or the CL Toco<sup>+</sup>MP transducer is applied. Smart Pulse is patent protected by Philips.

1. for example: Murray, M; Maternal or fetal heart rate. Avoiding intrapartum misidentification; JOGNN; 33, 93-104; 2004; DOI.10.1177/0884217503261161

## Measurement Principle


The two maternal pulse sensors under the plastic surface of the Toco MP Transducer (M2734B) and the CL Toco<sup>+</sup>MP transducer (866075) scatter infrared light through the bottom layer of the transducer. This light, which is invisible for human eyes, is reflected by tissue and blood vessels. The pulsating diameters of small arteries cause changes in the reflected light. The measured light changes are evaluated and a maternal pulse numeric is displayed and recorded.



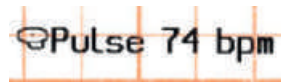
To improve accuracy, Avalon Smart Pulse uses two optical transmitters (infrared LEDs) and receivers. This creates two values from the two channels. Always the one having better signal quality is used for the display of the pulse numeric.

## Avalon Smart Pulse Application

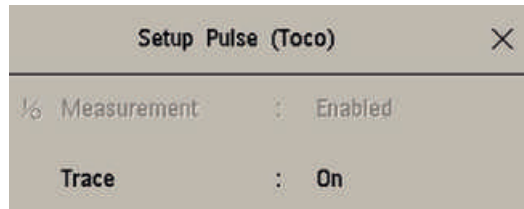
Apply the Toco transducer. Gel or water between the skin and transducer may compromise the measurement result. As soon as the transducer is applied, the Smart Pulse measurement starts automatically. A low-power infrared light, comparable to the remote control of a television device, lights up invisibly, and the optical receiver detects the reflected infrared light. After a few seconds, the monitor displays the Smart Pulse numeric together with the pulse signal quality indicator. The color of the Smart Pulse numeric is green by default (configurable).

On the trace recording, Smart Pulse is printed as a thin line, together with the — PULSE  symbol.

Together with the pulse rate in bpm, this symbol is also printed every five minutes on the trace paper.



In the **Setup Pulse (Toco)** menu, you can switch off recording the Smart Pulse trace on the trace paper. Select **Trace** to toggle between **On** and **Off**.



The Smart Pulse measurement can be switched off completely in Configuration Mode.

## Maternal Heart Rate (MHR) / Pulse Selection

The source for the MHR/Pulse numeric is selected automatically according to a ranking.

If you are monitoring MHR via MEGG electrodes, and/or you are monitoring SpO<sub>2</sub>, these measurements have priority over Smart Pulse from the Toco MP or CL Toco<sup>+</sup>MP transducer. Only Pulse from NBP has a lower priority.

Smart Pulse is continuously processed, so that it can take over immediately, and can be used for CCV, in a case higher priority measurement drops out. This also applies, if the higher priority measurement is not disconnected, but just delivers invalid values. This can be the case, if for example an SpO<sub>2</sub> sensor falls off. Because of this kind of back-up functionality, Smart Pulse can act like a safety net.

The MHR/Pulse selection follows the rules of the priority table below:

| Source                            | Priority                     |  |                      |                           | HR/Pulse Value |                                   | Features |             |       |
|-----------------------------------|------------------------------|--|----------------------|---------------------------|----------------|-----------------------------------|----------|-------------|-------|
|                                   | 1<br>HR<br>from<br>MECG      | 2<br>Pulse<br>from<br>SpO <sub>2</sub> | 3<br>Smart<br>Pulse  | 4<br>Pulse<br>from<br>NBP | On Screen      | On Paper<br>Trace                 | CCV      | QRS<br>Tone | Alarm |
| HR<br>from<br>MECG                | stable<br>value              | lower priority                         |                      |                           |                |                                   | yes      | yes         | yes   |
| Pulse<br>from<br>SpO <sub>2</sub> | unavailable<br>or<br>invalid | ↘<br>stable<br>value                   | lower priority       |                           |                |                                   | yes      | yes         | yes   |
| Smart<br>Pulse                    | unavailable or invalid       |  | ↘<br>stable<br>value | lower<br>priority         |                |                                   | yes      | no          | no    |
| Pulse<br>from<br>NBP              | unavailable or invalid       |  |                      | ↘<br>snapshot<br>value    |                | not applicable <sup>a,b</sup><br> | no       | no          | no    |

a. No pulse trace recording when NBP is the currently active pulse source.

b. Pulse from NBP is only printed on paper trace if NBP is pulse source at the time of the NBP measurement.

Due to motion artifacts, arrhythmia, or individual differences in pulse signal quality on the abdominal skin, it may become necessary to choose SpO<sub>2</sub>, or even MEGG measurement to derive a maternal heart rate.

No pulse limit alarm is issued when a Toco MP or CL Toco<sup>+</sup>MP transducer is the source of the pulse rate.


No QRS tone is audible when a Toco MP or CL Toco<sup>+</sup>MP transducer is the source of the pulse rate.

# Cross-Channel Verification

Avalon Smart Transducers allow all monitored heart rates to be compared with each other through the monitor's **Cross-Channel Verification (CCV)** feature. This can help significantly to reduce the possibility of mistaking one heart rate for another, for example, the maternal heart rate (MHR) for the FHR.


CCV compares all fetal and maternal heart rates continuously and indicates when multiple channels are picking up the same signal. This means that even when monitoring multiple fetal heart rates and the maternal heart rate simultaneously, CCV will compare the values from all fetuses and each of these values with the maternal heart rate.

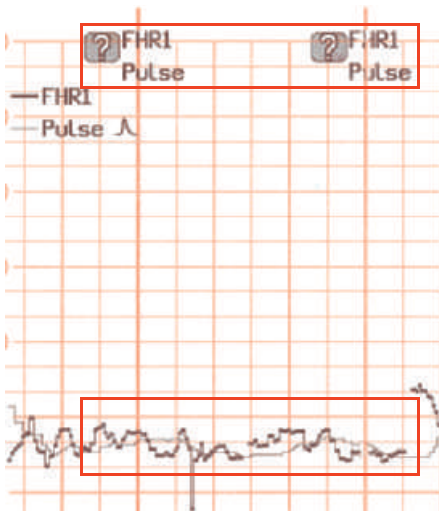
Philips recommends also to monitor the maternal pulse via the Toco MP or CL Toco<sup>+</sup>MP transducer, the SpO<sub>2</sub> measurement, or the ECG measurement, to avoid the possibility of mistaking the maternal heart rate (MHR) for the FHR.

CCV indicates when the same heart rate is being measured by different transducers. On the screen, the coincidence indicator  is displayed next to the affected numerics.



Coincidence Indication on the screen

...and  is repeatedly printed on the trace after about 30 seconds after detecting the coincidence, showing which heart rate channels are coinciding.



Coincidence Indication on the Trace

CCV technology helps reduce potential legal liability associated with continuing to monitor an incorrect heart rate.

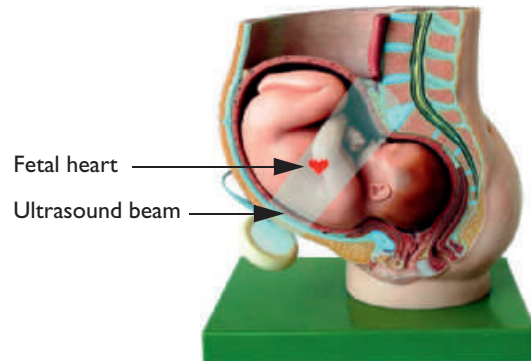
The INOP **Coincidence** is now by default a yellow INOP with tone that is issued immediately when the coincidence situation is detected.

For the INOP **Coincidence** a configurable delay can be set to either 30 seconds or 60 seconds. If a delay is configured, the INOP Coincidence is issued first in cyan without tone, and after the configured delay, it turns into a yellow INOP Coincidence that is issued with tone.



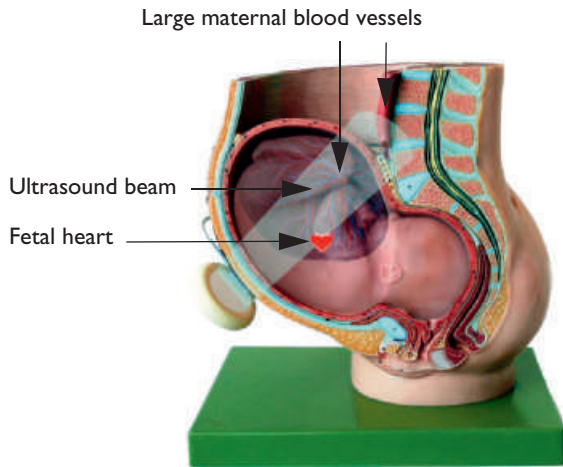
If you are monitoring externally, check the trace and reposition one of the transducers, if necessary, to detect a related HR correctly.

The following picture shows the ultrasound transducer well positioned with respect to the fetal heart.



Even with a currently well-positioned ultrasound transducer, CCV continuously gives you added assurance that the fetal heart is the signal source for the monitored heart rate. When the maternal heart rate and fetal heart rate are being monitored, CCV will warn you when the values could be from the same source.

This may happen following fetal or maternal position change, where the fetal heart is no longer fully within the ultrasound beam, and the transducer is picking up a signal from another source, most likely from another fetal heart (when monitoring multiples) or from a large maternal blood vessel as shown in the picture below.



**Note:** Be aware that a maternal heart rate trace can exhibit features that are very similar to those of a fetal heart rate trace, even including accelerations and decelerations. Whenever CCV displays question marks, reposition the US transducer.



Do not rely solely on trace pattern features to identify a fetal source. If necessary, identify the FHRs using independent means, such as a stethoscope or ultrasound imaging.

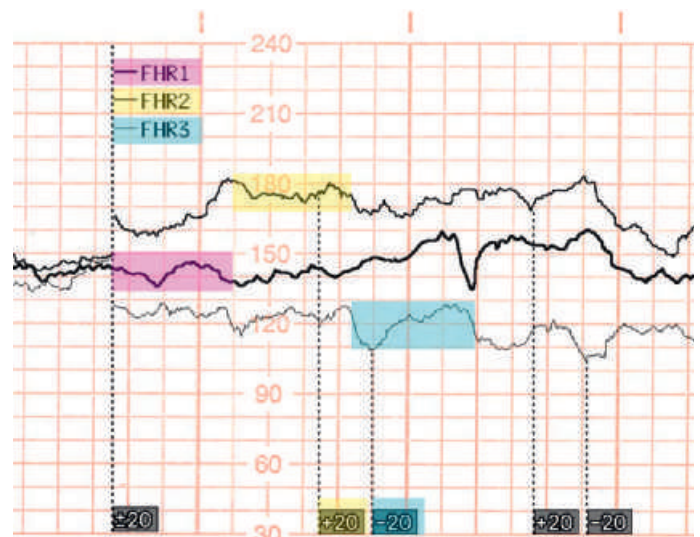
## Trace Separation

The baselines of two or multiple FHR traces are often very similar, and when this occurs, independent trend interpretation can be challenging. To ensure that the three heart rates are easily distinguishable, Avalon Smart Transducers and Fetal monitors employ the **Trace Separation** feature which separates the baselines on the recording.

You can choose to separate the baselines on the recorder print-out by an offset, so that the traces for FHR2 and for FHR3 are shown higher or lower than they really are. Two different ways of separation are configurable:

### Standard

The FHR2 trace is shifted up by 20 bpm (it is recorded 20 bpm higher than it really is). No offset is ever applied to the FHR1 trace - it stays where it is. (In case of a third FHR, this is shifted down by 20 bpm.)



Triplets trace separation standard

### Classic

The FHR1 trace is shifted up by 20 bpm when there is more than one FHR measurement. No offset is ever applied to the FHR2 trace - it stays where it is. (In case of a third FHR, this is shifted down by 20 bpm.)

The numerical value for the fetal heart rate displayed on the screen is, of course, the real fetal heart rate without any offset.

You can turn off the trace separation feature and return the FHR trace to its original baseline anytime you wish.

Refer to the application note, “Monitoring Triplets”, for further information about the Trace Separation feature.

## Fetal Movement Profile

Avalon Smart Ultrasound transducers support Philips’ Fetal Movement Profile, a parameter provided by Philips Fetal monitors, and which has been accepted as an important additional tool for assessing fetal well-being.

Introduced in 1991, Philips Fetal monitors simultaneously assess fetal heart rate (FHR) and fetal gross body movement via the Fetal Movement Profile (FMP) parameter from the Ultrasound transducer.

Recordings of fetal movement are increasingly being obtained as part of routine antepartum screenings in obstetricians’ offices, clinics, and hospitals.



Benefits of the FHR-FMP assessment range from:

- helping clinicians determine the baseline heart rate - especially in difficult-to-interpret traces, to
- predicting and supervising high risk pregnancies which involve a number of fetal disorders, including fetal growth retardation (IUGR).

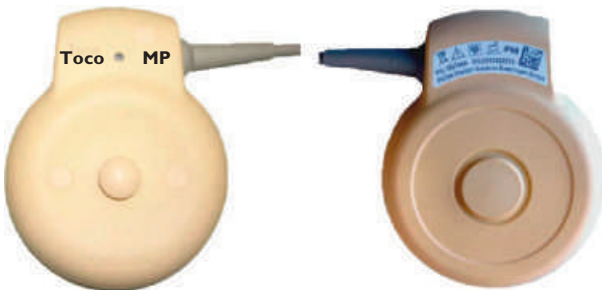
One of the most important benefits of Philips' FMP monitoring is its efficiency and cost effectiveness as an early screening tool.

Clinical trials have confirmed that the use of Philips Fetal monitors in routine antepartum screenings reduces the number of patients with "suspicious" FHR test results, thus eliminating their need for additional expensive, second-level testing at the hospital. For the patient, this represents significant savings in time, cost, and concern. It also means cost savings for the health care system.

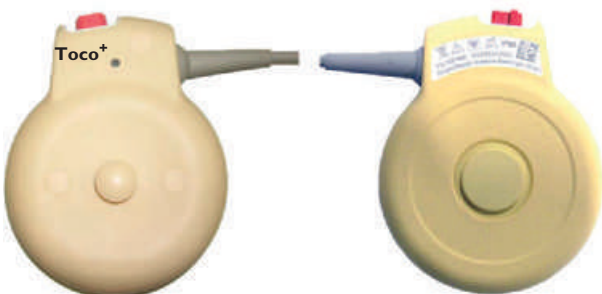
Together with Precision Signal Track and Hold, Cross-Channel Verification, and Trace Separation, FMP represents a significant contribution to safety and accuracy in fetal and maternal monitoring.

## The Smart Transducer Family

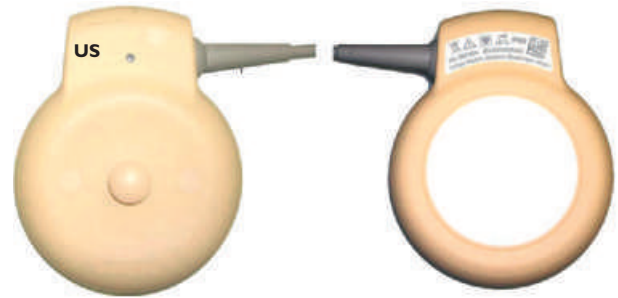
### Toco MP Transducer (M2734B)



### Toco<sup>+</sup> Transducer for Toco/ECG/IUP (M2735A)



### Ultrasound Transducer (M2736A/M2736AA<sup>1</sup>)



### Patient Module for ECG/IUP (M2738A)



1. The M2736A and M2736AA transducers are equivalent. M2736AA is for USA only.

# The New Generation of Smart Transducers the Avalon CL Transducer System

The new Avalon CL Transducer System is a plug-and-play solution that connects the CL base station like a cabled fetal transducer to the fetal socket at the Fetal monitor, or in case of the FM40 and FM50 also to the Telemetry socket. The CL transducers can be used exactly the same as their cabled counterparts and have the same reliability within their operating range of 100 m (300 ft.) in line-of-sight around the base station as the cabled transducers. When a CL transducer is enabled, all cabled transducers are disabled. The mother is able to walk and move around during fetal monitoring, and can even be monitored under water. To monitor with the Avalon CL Transducer System, you require the software revision J.3 or higher on the Fetal monitor.

## Avalon CL Base Station (866074)



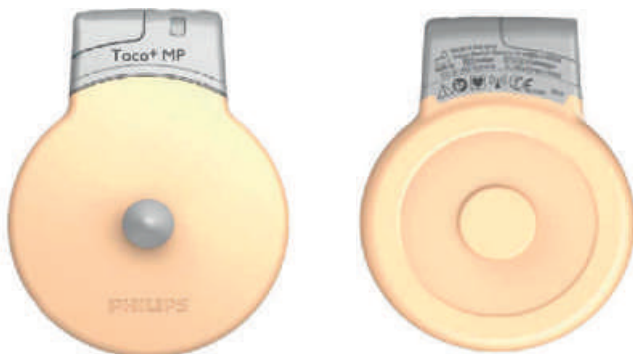
## CL Ultrasound Transducer (866076)



## CL ECG/IUP Transducer (866077)



## CL Toco+MP Transducer (866075)





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