Modelling and simulation of driving cycle using simulink

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Article Info

ABSTRACT

Driving cycle is commonly known as the relationship and a series of speed-time profile. The study on this discipline aids vehicle manufacturers in vehicle construction, environmentalists in studying environment quality in proportion with vehicle emissions and traffic engineers to further investigate the behaviour of drivers and the road conditions which assist automotive industry in a better and energy efficient vehicle productions. In order to develop a proper driving cycle for selected routes, information and data based on real-time driving behaviour is important. This research focusses on the modelling of each component and latter designing a conceptual model in Simulink which takes up the data of speed of vehicles in SI unit which is m/s and draws out distance travelled and acceleration of the vehicle together with driving cycle of the route for given timestamp. This relation will be verified with existing Kuala Terengganu BasKITe driving cycle, highway fuel economy test (HWFET), new europian driving cycle (NEDC) and worldwide harmonised light vehicle test procedure (WLTP) driving cycles for the use of future projects and improvements of technology in studies and analysis of powertrain and electric vehicle performances.
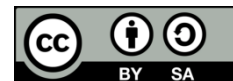
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1. INTRODUCTION

Automotive industries face some challenges and pressure to reduce their development times when they are about to innovate and produce unique products. According to James [1], the need tor educe emissions in automotive sectors provides a more related and connected experiences and demand for autonomous and simulators. Driving cycle plays an important role in automotive sector where engineers requires driving cycle to analyze road condition, road profile, driving behavior, fuel consumptions, fuel emissions and road conditions and latter aids vehicle manufacturing sectors in more efficient vehicle productions [2]-[5]. Driving cycle is a profile which represents a speed-time relationship in which can be used to draw out fuel economy of a vehicle [6]-[10]. According to Polizanno and Saletti [11], working efficiently is indispensable to success in a globalized market, especially for high-tech industries such as automotive, aerospace and communications, where electronic controls are a vital part of each new product. The increasing demand of simulation and software use in application domains has resulted in a staggering complexity that has proven difficult to manage with conventional design approaches. Due to the ability of embedded software and simulations to determine complexity and challenges, model-based designs and

modelling is becoming vital among engineers. As stated by Hayfield [12], automotive industries are moving towards new decades where vehicle autonomy had been one of the important improvements needed the most in which the use of technologies are vital to automate and simulate some or all driving functions. As time and technology is proceeding, the amount of work modern software has to perform is always growing more, thus resulting in the amount of complexity of the programs and software becoming bigger. Mainly for automotive simulation application, a product of MathWorks also well-known as Simulink is widely used as it has the ability and functions of powertrain block set, vehicle dynamics block set, automated driving toolbox and model-based calibration toolbox. Some of the models which are constructed using Simulink are fault-tolerant fuel control system, data management for a fuel control system using data dictionary, engine timing using triggered subsystems, engine timing model with closed loop control, building a clutch lock-up model, anti-lock braking system, automotive suspension. This research and study on Driving Cycle discipline uses common block set in Simulink such as signal builders and subsystems to do interpolation of signals and produce driving cycle relation by mean of integration and derivation from speed.

2. SIMULINK

Simulink is a product of MATLAB that provides interactive modelling, simulating and analysing system in the form of graphical and block interface. It enables quick and effective production and innovation of virtual prototypes to explore design to any extent with minimal effort. According to Baloi *et al.* [13], Simulink provides a graphical user interface (GUI) for building models as block diagrams and it includes a library or defined blocks which can be used to design simulation as desired. Besides, user can also define blocks separately with custom formulas according to required applications in subsystems which ease the production of simulation designs

2.1. Simulation applications in the automotive industry

According to Zeigler *et al.* [14], simulation analyses are divided into two major subcategories; discrete-event simulation and continuous simulation Continuous simulation studies processes amenable to analysis using differential equations in which can be applied in the field of ecological systems, chemical synthesis and manufacturing, refinaries and aerodynamic system designing whereas discrete-event simulation studies processes in which most of the used variables are integers and not amenable to be used in continuous equations. According to Miller and Pegden [15], individuals tend to learn simulation quicker and understood that simulation is a delightfully quick, inexpensive, and non-disruptive alternative to the potential purchase, installation, and integration of expensive machines or material-handling equipment. In automotive industry, simulation allows manufacturers to imagine new systems and enables them to estimate the final outcome if for all models and designs made and also to observe the behaviour. Whether the system is a production line, operating system, control system or an emergency response system, simulation and modelling can be used conduct pre assessment on the suystem they are about to built and collect data and information to move further or before constructing a prorotype of a device, machine or a system in vehicles.

Several automotive related simulation projects were conducted all over. Firstly, Law and McComas [16] discussed steps of a sound simulation study and secrets of a successful industrial simulation. A case study to select the best system from a few proposed systems related to production using simulation were described and discussed by Scriber [17]. Besides, Azadeh and Farid [18] comes up with an integrated simulation model which generates optimization alternatives for heavy rolling mills for a steel-making factory. Patel *et al.* [19], studied on the methodology of modelling and research on final process systems of automobile processes to develop efficient process to ensure quality output of the system. Choi *et al.* [20], discussed the initial efforts to implement simulation modelling as a visual management and analysis tool at automotive foundry plant manufacturing engine blocks. To add on to that, Potoradi *et al.* [21], described simulation engine can be run in parallel with a large number of products on wire-bond machines. Altiparmak *et al.* [22], improvised analysis and decision-making processes by using simulation metamodels of an asynchronous assembly system in buffer size optimization. Last but not least, Norbakyah and Salisa [23], conducted a study on plug-in hybrid recreational boat (PHERB) powertrain with a special energy management strategy modelling and analysis using Simulink. To add to that, Williams and Ülgen [24], divides automotive simulation into two categories which is manufacturing simulatyion and automotive industru simulation. According to Edward, manufacturing simulation is one of the first major application areas of discrete-event process simulation whereas automotive industry involves them in a very large supply chain apex.

2.2. Conceptual design in Simulink

According to Daltrophe *et al*. [25], function blocks can always be inter-transformed and interchanged to suit the application of automation and autonomous system which is in line with the standard of IEC61499 in order to validate the complexity of the simulating environment. In this study, a few blocks from Simulink library were used such as digital clock, signal builder, hit crossing, saturation, rate transition, integration and derivative blocks, subsystems, basic operation blocks, gain, mux, bus creator and selector, scope and on-screen scope. A database in form of Excel file with speed data will be uploaded into signal builder and the stop time of the simulation will be amended according to applications. Signal Builder > Import from files > Browse > choose file > OK. Example of file import is as per Figure 1.
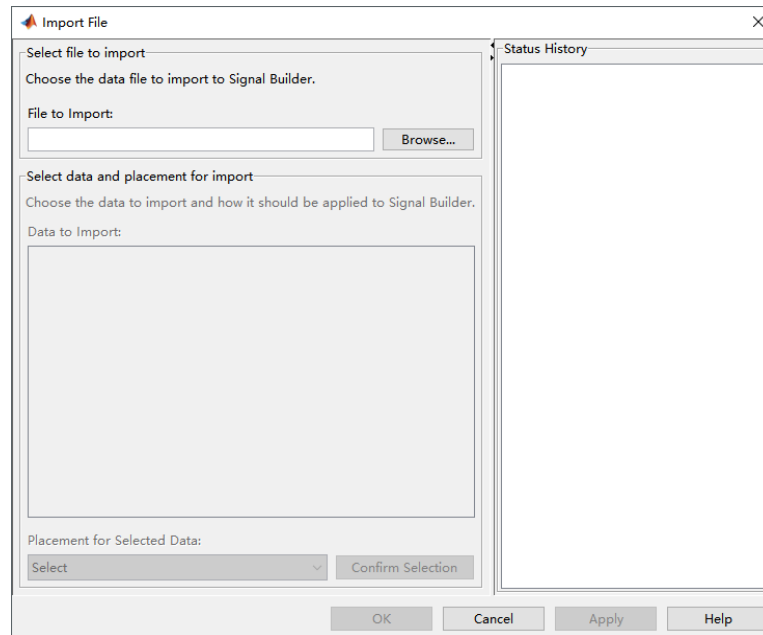
Figure 1. Data file import

3.   RESULT AND DISCUSSION.

3.1. Conceptual design in Simulink

The development of Simulink design begun with the analyis on the availability of the data collected such as speed, acceleration, displacement of distance travelled. In this conceptual design, only speed data is required where distance travelled will be calculated by integrating speed and the data of acceleration will be obtained through the first derivative of speed. The formulas of calculation varies depending on availability of types of data. After obtaining three required data which is distance, speed and acceleration, interpolation of distance and speed data is done in a subsystem. According to Lepot *et al*. [26], interpolation of data is carried out to fill gaps in time-series efficiency criteria and incertainty quantifications. In addition, Daltrophe *et al*. [27], ecxplained an efficient sampling alternative for a sensor aggregated data points using big data interpolation. In this research, data interpolation is important to filter out unnecessary data points and to fill in gaps between points with relevant points as a method to mitigate noises and irrelevant errors due to high sensitivity of the sensor. The main use of data interpolation is to aid the study and analysis of data which might exist outside their collected data. Interpolation is also frequently used to convert the sampling rate of digital signals to estimate an unknown potential yield. Figure 2 shows the conceptual design of the simulation. Distance is interpolated in the "Distance Interpolator" subsystem according to Formula 1 whereas velocity is interpolated in the "Velocity Interpolator" subsystem according to Formula 2. Since magnitude and vector is negligible in this case, data of speed will be used as velocity and distance will be used as displacement.

$$s(n) + \frac{a(n)}{2} dT^2 + v(n)dT = s \tag{1}$$

$$a(n)dT + v(n) = v(t) \tag{2}$$

Where, s is distance/displacement, m, v(t) is speed/velocity, m/s and (t) is acceleration, m/s^2.
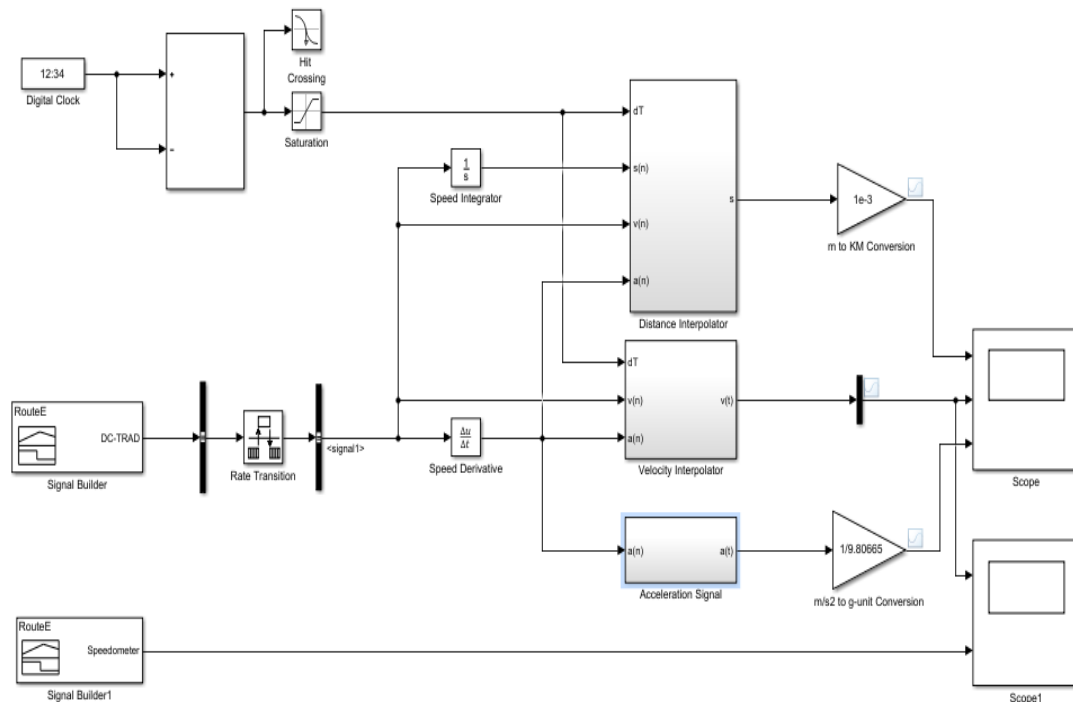

Figure 2. Driving cycle conceptual design and model in Simulink

A "gain" block is used with multiplication of 1e-3 or equivalent to division of 1000 to convert the unit of distance from m to KM. The unit for velocity is remained as m/s and the unit of acceleration is converted from m/s^2 to acceleration with gravitational force which is g-unit by multiplication of 1/9.80665. The final 3 signals are connected to scope to be monitored and analyzed. Several established driving cycles have been chosen to verify the conceptual design; Kuala Terengganu BasKITe driving cycle, HWFET, NEDC and WLTP. Figures 3 (a)-(d), Figures 4 (a)-(d), Figures 5 (a)-(d) and Figures 6 (a)-(d) shows the results obtained.

The first axis of simulation results shows distance travelled, second axis shows driving cycle relation with time and third axis shows acceleration. This procedure is carried out by connecting collected data into velocity interpolator and also to a separate scope in which interpolated signal and direct signal is applied to compare the required and acquired data. In all the above figures, the acquired data overlaps required data in which can be concluded as zero signals lost throughout the simulation. To prove this, as per Figure 3 (c), Figure 3 (d), Figure 4 (c), Figure 4 (d), Figure 5 (c), Figure 5 (d), Figure 6 (c) and Figure 6 (d), comparison was done at 25% and 75% of the total elapsed time for each driving cycle. For Kuala Terengganu BusKITE driving cycle, comparison was done at the time of 655 and 1963 which gives ΔY=0. HWFET driving cycle was compared at the time of 192 and 575. NEDC driving cycle was compared at the time of 295 and 885 whereas WLTP driving cycle was compared at the time of 450 and 1350. The end result for each driving cycle gives ΔY=0 in which the constructed conceptual design does not lose any signal in accordance throughout the simulation process. Signal lose identification is important in any simulation processes and procedures as it may give out inaccurate and inconsistent final result. To ensure minimal signal losses in simulation, it is crucial to identify types of blocks and functions being used, the rate of signal losses and also appropriate insertion and return signal paths are chosen. In most cases of simulation, signals are often lost during return process as a due part of the simulation consumes certain decibels of it during initialization. On the other hand, the default input data into signal builder is in m/s, which is the SI unit of speed. Figure 7 are some of the direct conversions using "gain" block. It is also advisable to convert the values in the Excel datasheet before uploading into signal builder to ensure consistency of data points being generated and simulated.
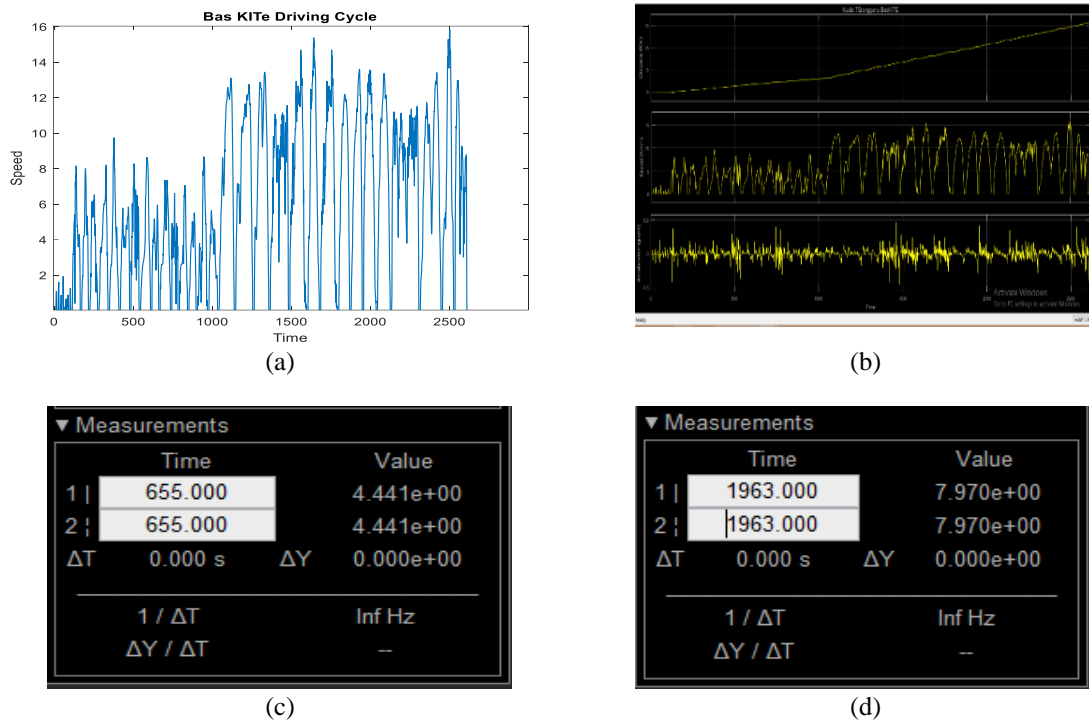
Figure 3. (a) Established kuala terengganu BasKITE driving cycle; (b)simulated kuala terengganu BusKITE driving cycle; (c)measurement at time 655; and (d)measurement at time 1963
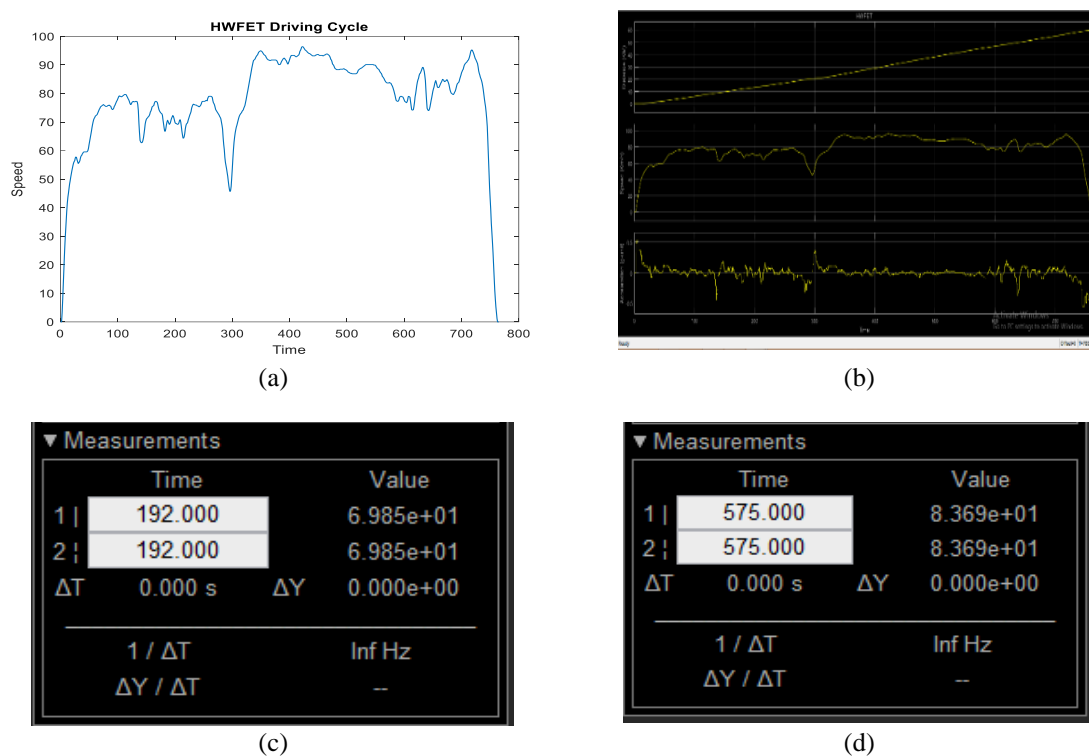

Figure 4. (a) Established HWFET driving cycle; (b) simulated HWFET driving cycle; (c) measurement at time 192; and (d) measurement at time 57
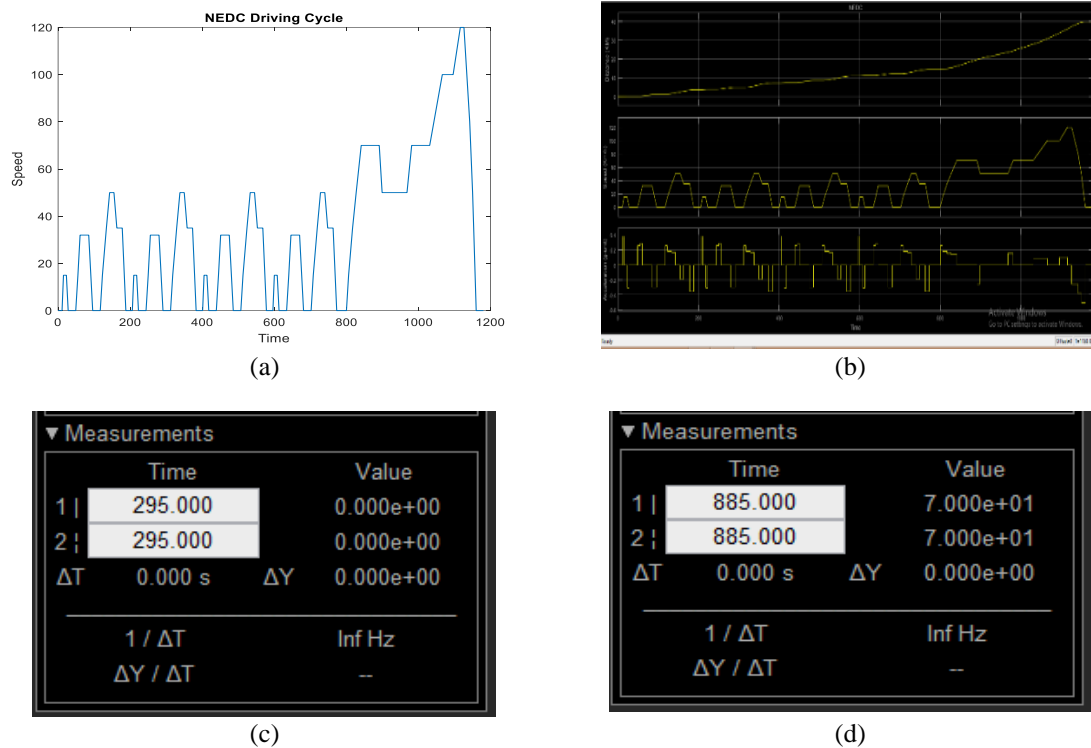
(a)

(b)

(c)

(d)

Figure 5. These figures are; (a) established NEDC driving cycle; (b) simulated NEDC driving cycle;
(c) measurement at time 295; and (d) measurement at time 885
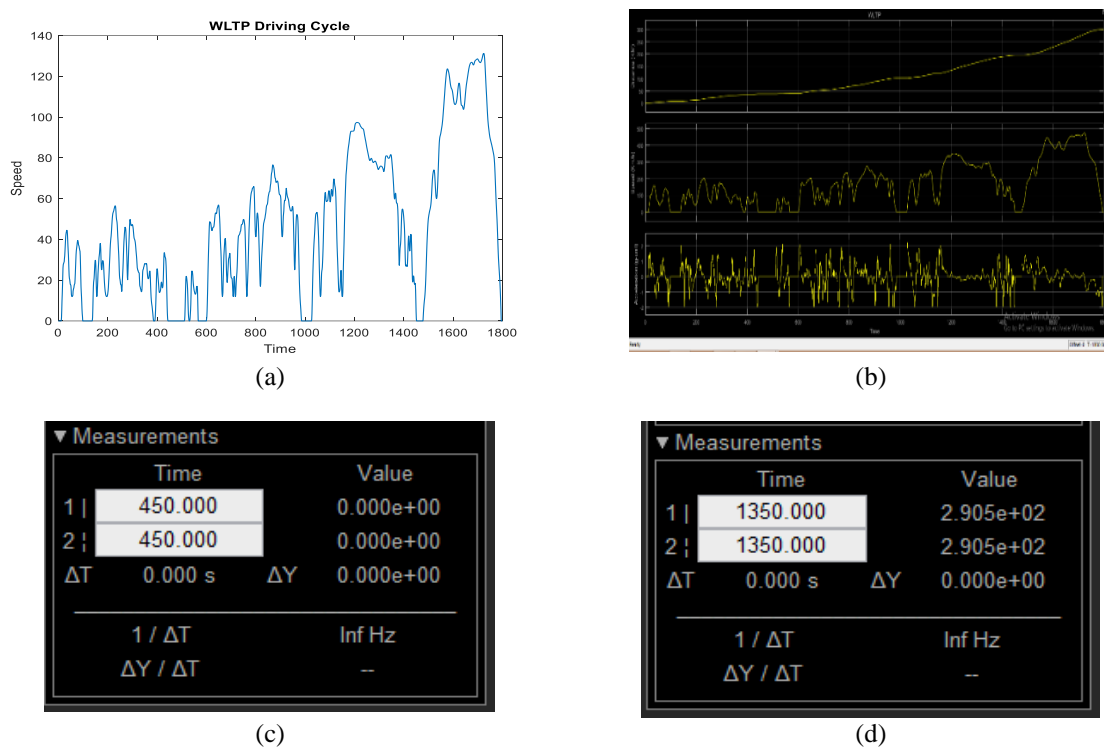

(a)

(b)

(c)

(d)

Figure 6. These figures are; (a) established WLTP driving cycle; (b) simulated WLTP driving cycle;
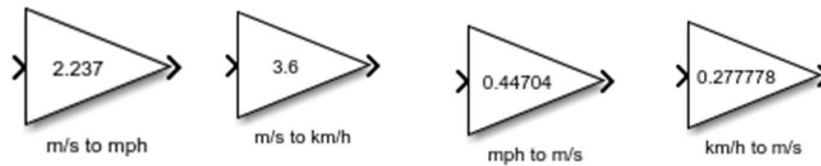(c) measurement at time 450; and (d) measurement at time 1350

Figure 7. Direct conversion using "gain" block

4. CONCLUSION

In the nutshell, driving cycle conceptual designing and modelling in Simulink is successful and can be wrapped up and verified since the result of the simulation gives zero error compared with four established driving cycles which is Kuala Terengganu BusKITE, HWFET, NEDC and WLTP driving cycles. The conceptual design therefore can be used in future to simulate driving cycles by uploading the data of speed of vehicles into signal builder in the format of Excel to further analyse the emissions and driving behaviours of individuals. The novelty of this research is proven as the use of Excel in daily life has increase drastically to perform calculation, visualization and analysis of data and proven to be one of the platforms used by various business and research sectors. Since there are no any researches conducted previously to link the use of Excel and Simulink to construct driving cycle, this opportunity was taken to design a conceptual modelling of driving cycle in which the relationship of speed and time can be used to analyze various information required by traffic engineers and environmentalists. In accordance, Excel had been chosen to be used in this research as the data collected to construct driving cycle can be tabulated and simulated at the same time and directly uploaded into signal builder of conceptual design to undergo required processes.

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